Australian Government

Nuclear-based science benefiting all Australians

27 July 2009

The Secretary
Select Committee on Fuel and Energy
PO Box 6100
Parliament House
CANBERRA ACT 2600

Dear Sir

Inquiry into Fuel and Energy

Please find attached ANSTO's submission to the Select Committee for Fuel and Energy. Please do not hesitate to contact me as ANSTO would be pleased to follow up with the committee.

Yours sincerely

DR RON CAMERON
Executive General Manager
Strategy, Government and International Relations

The role of nuclear in enhancing energy security in Australia

A submission to the Select Committee for Fuel and Energy

Australian Nuclear Science and Technology Organisation
July 2009

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1 Executive summary

The main energy challenges for the world today are providing a secure and reliable source of energy to keep up with the increasing global demand, while urgently reducing greenhouse gas emissions to limit the effect of climate change. The world wide demand for energy is predicted to increase by a factor of 2.5 by 2050 (electricity use globally increased by a factor of 3 between 1973 and 2006). The International Energy Agency in their 2008 World Energy Outlook have clearly asserted that current global trends in energy supply and consumption are unsustainable.

The challenges of ensuring security of supply and reducing greenhouse gas emissions are key issues for Australia, as 93 % of electricity generation comes from burning fossil fuel, of which coal makes up 81 %[1]. Consequently, Australia has one of the highest CO_2 emissions per capita. Growth in electricity demand in Australia is expected to be approximately 2% per year[2], which will continue to increase greenhouse gas emissions if changes are not made to Australian energy policies. The problem is sufficiently serious that all electricity generation technologies should be under active consideration, even if these do not eventually meet the criteria for adoption.

There is, and will continue to be, a direct link between Gross Domestic Product growth and energy requirement growth in resource based economies. Australia remains a resource based economy.

Nuclear power plants are a proven technology that can provide low carbon electricity generation, in a reliable, safe and affordable manner. Introducing nuclear power generation into the energy mix would: increase diversity of supply; support the government's objective of carbon pollution reduction; mitigate future trade risk in a carbon penalising trade regime globally; and achieve this without major impact on economic prosperity.

In this report we conclude that:

1. Current trends in global and domestic energy demand and consumption are expected to continue. These rates of increase are, however, unsustainable, and threaten both security of energy supply and climate stability.
2. A secure energy supply is characterised by good adequacy, reliability and affordability. It must also be environmentally sustainable, and have minimal adverse health effects. This is best achieved through the use of a diverse mix of low carbon and low pollution energy sources.

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[1] Australian Energy Market Operator (AEMO); *An Introduction to Australia's National Electricity Market*; July 2009

[2] Australian Bureau of Agricultural and Resource Economics (ABARE); *Australian Energy - National and state projections to 2029-30 – abare research report 06.26*; December 2006

3. Most developed economies and a number of developing economies include nuclear power in their long-term energy security strategy. Australia is one of very few OECD countries not embracing nuclear power.
4. All OECD countries (except Australia, New Zealand and Iceland) that have not embraced nuclear power can and do import nuclear power from contiguous economies that have nuclear power. Australia will not have this option available to it – a significant negative for energy security if the intention is to remain a leading economy.
5. Australia currently relies almost exclusively on fossil fuels (especially coal) for its electricity supply. This lack of diversity and current dependence on sources with high greenhouse gas emissions makes Australia's future energy supply insecure. Australia's economic position becomes more vulnerable if a price on carbon is introduced.
6. The current policy of pursuing clean coal and renewables is a necessary but not sufficient strategy in the light of the climate change challenge. Renewables cannot yet provide early or proven solutions to the problems Australia faces. Depending on affordable clean coal being available in a short time frame is not supported by the science or the technological maturity of the technologies or the required regulatory assurance. The assumptions that underpin policy optimism in this regard cannot be sustained. In fact, worldwide evidence is that clean coal will not be economical in the required timeframe.
7. Nuclear power generation is a mature, proven technology that has provided base load power in a number of countries for 50 years. It has a number of advantages such as fuel price stability, low operating costs, low emissions and waste and, for Australia in particular, a secure fuel supply. Nuclear power has much to offer in the way of achieving a diverse energy mix, and thus, ensuring medium to long term energy security.
8. South Korea and Japan have continued to build nuclear plants in the "nuclear winter" that preceded the current nuclear renaissance and have developed good practices in both nuclear industrialisation strategy and regulatory processes from which Australia can learn.
9. The nuclear power industry in the developed world is the only electricity generator that also pays for its full lifecycle costs, including the cost of managing the waste it produces.
10. Nuclear power merits serious consideration as an option for Australia. The consideration should be based on a full evidence-based examination of the available technology along with a range of other technologies using established levelised cost analysis and properly pricing carbon within the analysis.
11. The best model of reactor to use for Australia would be a proven, reliable Generation III model (more passive safety systems and standardised plants than Generation II). These include the EPR (AREVA), AP1000 or AP600 (Westinghouse/Toshiba), ABWR (General Electric/Hitachi or Toshiba) or the ESBWR (General Electric/Hitachi). By the time, Australia makes a decision on any

of these designs, there will be enough built or under construction that "first of a kind" issues will have been resolved.

12. Despite its maturity, it is clearly recognised that there a number of important public concerns raised about nuclear, including waste, proliferation and safety. These issues have been extensively examined in many countries and by many studies. These conclude that technological advances in the industry and its regulation mean that the residual risks are well controlled.
13. Active public engagement, transparent, clear information and factual debate have been shown in other countries to significantly allay public concerns. Independent, strong regulators are also seen to be key to public confidence.
14. Significant regulatory and legislative reform must be undertaken in order for nuclear power to be established in Australia. Such reform is best achieved through sustained bipartisan support. Public education and community engagement are also merited so that debate and decisions are fact-based and transparent.
15. Concerns are also raised about the cost of nuclear power, due to its requirement for high initial capital investment. This requires special funding mechanisms and government support to reduce the risks from delays and provide incentives for investment. This is no different to the support given to other forms of energy production. Nevertheless, appropriate accounting for greenhouse gas and other emissions has made nuclear a competitive option in relation to existing coal and natural gas plants and a much better low carbon source.
16. While there are a number of ways to provide a secure and diverse energy mix for Australia, all will require reducing reliance on current fossil fuel technologies, and nuclear power, in combination with renewable energy technologies, satisfies the criteria for being considered a key technology.
17. Australia's energy security from a trade and economic point of view will be severely compromised if nuclear energy is not actively considered as: the future cost of carbon is not known and all renewable options are intermittent low power density sources that cannot be relied on for energy intensive processes such as transport and logistics infrastructure, national defence facilities/deployment, and economic extraction of natural resources, which form the bulk of Australia's trading income.

2 Introduction

The main energy challenges that the world faces today are providing a secure and reliable source of energy to keep up with the increasing global demand, while urgently reducing greenhouse gas emissions to limit the effect of climate change. It is recognised by the International Energy Agency in their 2008 World Energy Outlook that current global trends in energy supply and consumption are unsustainable. As a dry continent, Australia will be greatly affected by global warming resulting from climate change.

The challenges of ensuring security of supply and reducing greenhouse gas emissions are key issues for Australia, as 93% of the electricity generation comes from burning fossil fuel[3]. Australia has one of the highest CO_2 emissions per capita in the world and this will continue to rise in line with growth in electricity demand, which is expected to be approximately 2 % per year[4], unless changes are made to government energy policies. The carbon pollution reduction scheme represents one such change but needs to be implemented by using technologies capable of producing significant reductions in greenhouse gas emissions.

Good characteristics of a national energy mix are diversity of supply, low carbon production and reliability of supply in an affordable manner. Many other countries have recognised these issues. For example, the UK Energy White Paper enunciated a strategy to save energy, develop cleaner energy supplies and secure reliable energy supplies at prices set in competitive markets. The UK intends to achieve these aims by binding targets for greenhouse gas reductions and including an expanded role for nuclear power as part of the energy mix.[5]

The magnitude of the energy supply challenge, both globally and nationally, requires a wide range of solutions and both available and future technologies should compete on their merits. The problem is sufficiently serious that all technologies should be under active consideration, even if these do not eventually meet the criteria for adoption.

This submission will address the above issues in an Australian context, focussing mainly on the role of nuclear in contributing to enhanced energy security for Australia. ANSTO's submission to the UMPNER[6] process and to the energy white paper discussion reports provide more details on the seriousness of the greenhouse gas (GHG) issue globally and on nuclear power's contributions to GHG reductions.

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[3] Australian Energy Market Operator (AEMO); *An Introduction to Australia's National Electricity Market*; July 2009

[4] Australian Bureau of Agricultural and Resource Economics (ABARE); *Australian Energy - National and state projections to 2029-30 – abare research report 06.26*; December 2006

[5] Department of Trade and Industry; *Meeting the Energy Challenge – A White Paper on Energy*; United Kingdom; May 2007

[6] Department of the Prime Minister and Cabinet, *Uranium Mining Processing and Nuclear Energy – Opportunities for Australia?*, Canberra, 2006

The topics covered in this report are:

- The current global and Australian energy situation
- Why there is a global renaissance in nuclear power generation
- How nuclear power generation can provide security while reducing Australian CO_2 emissions
- The appropriate choice of reactor technology for Australia
- Advantages and disadvantages of nuclear power in the Australian context
- Regulation and legislation
- An analyses of the economics of nuclear power

3 Current energy situation

3.1 Worldwide

3.1.1 Global energy mix

Currently there are numerous technologies for generating electricity, and different countries use different energy mixes that suit the environment of each country. Figure 1 shows the current mix of electricity generation throughout the world. As can be seen, the major share of electricity around the world is produced by fossil fuels.

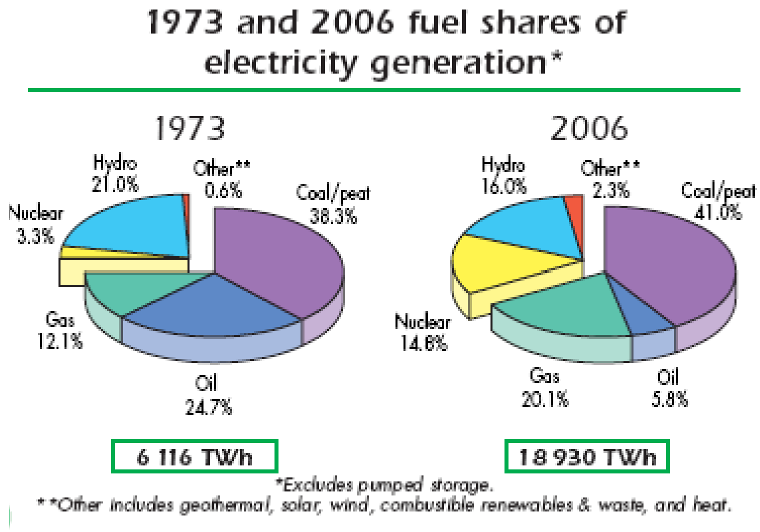

Figure 1 Global fuel shares of electricity generation for 1973 and 2006[7]

3.1.2 Nuclear power around the world

As of February 2009, 30 countries worldwide were operating 436 nuclear reactors for electricity generation and 45 new nuclear plants were under construction in 14 countries.[8] As can be seen in Figure 2 below, the United States has the largest nuclear

[7] International Energy Agency; *Key World Energy Statistics*, 2008

[8] Nuclear Energy Institute; *World Statistics*, Feb 2009; http://www.nei.org/resourcesandstats/nuclear_statistics/worldstatistics/ accessed on 15-7-09

capacity, followed by France, Japan and then the United Kingdom; however France has the largest percentage of total electricity supplied by nuclear, shown in Figure 3.

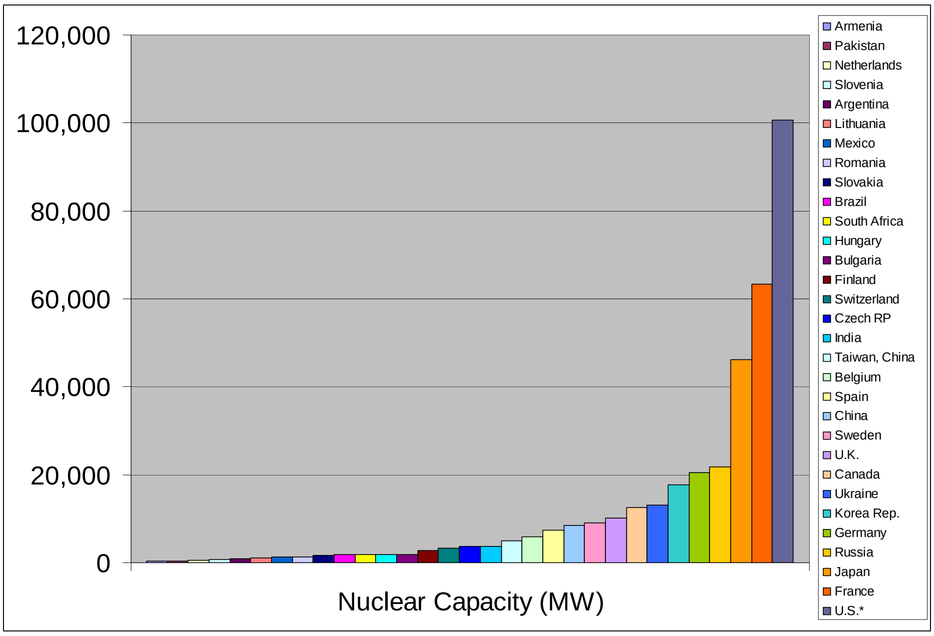

Figure 2: Nuclear capacity for nuclear energy producing countries 2007 from Nuclear Energy Institute[9]

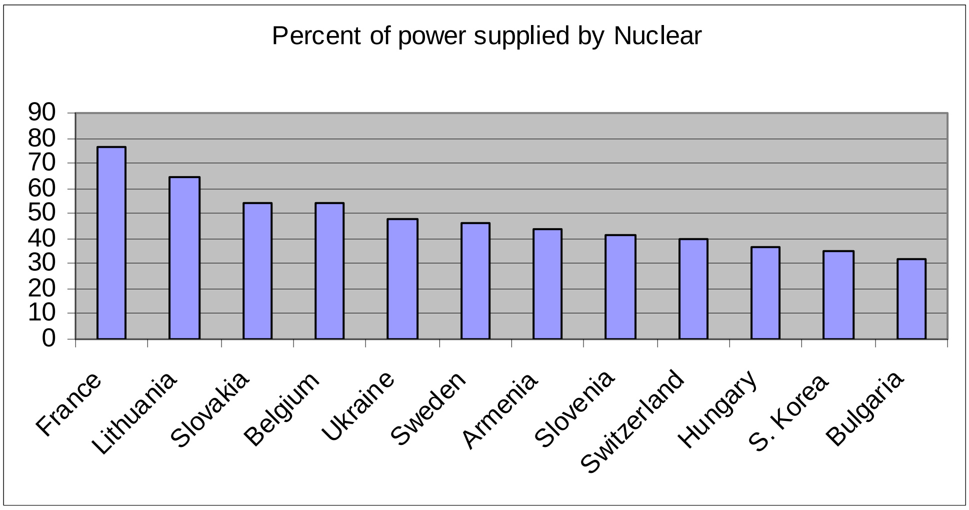

Figure 3: Nuclear electricity generated as percentage of countries total electricity generation[10]

3.1.3 Growth of Energy consumption

Energy demand globally is increasing, and the increase cannot be stopped without denying countries the right to economic prosperity or maintenance of their standard of living. According to the NEA Nuclear Energy Outlook 2008, by 2050, if policies remain

[9] Nuclear Energy Institute; World Nuclear Generation and Capacity (2007); http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/worldnucleargenerationandcapacity/

[10] Nuclear Energy Institute; World Statistics (2008); http://www.nei.org/resourcesandstats/nuclear_statistics/worldstatistics/

unchanged, primary energy demand is expected to have increased by a factor of about 2.5, the primary drivers for the expected increases will be the strong economic growth in many developing countries, leading to a more energy-consuming lifestyle, and the projected expansion in world population.[11] It is stated in the World Energy Outlook 2008 by the IEA that current global trends in energy supply and consumption are unsustainable – environmentally, economically and socially and there is need for global policy reform related to energy generation and supply.[12]

Figure 4 shows a set of predicted data for two scenarios for global electricity generation mix for the future that was shown in the Key World Energy Statistics 2008 by the IEA.

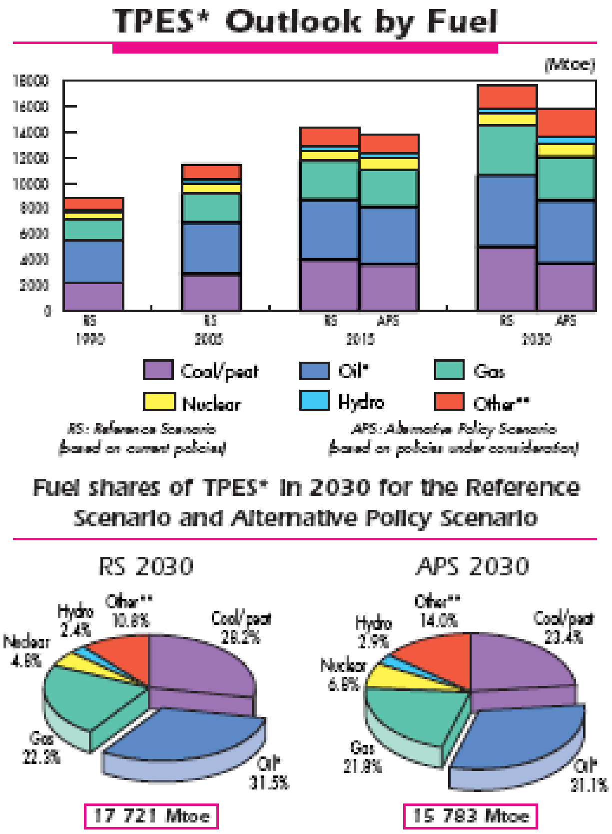

Figure 4: Outlook for World Total Primary Energy Supply (TPES) for IEA predicted future scenarios[7]

In both scenarios fossil fuels still play a large role in electricity generation. However, there is a larger projected increase in renewable and nuclear generation in the alternative scenario which is the preferable option due to the associated decrease in greenhouse gas emissions.

In considering some of the alternatives for base load generation, we note the uncertainties on the availability and price of oil and gas. The industry projection for oil production (see Figure 5 below[13]) shows a growing shortfall in supply in the future – the "peak oil" phenomenon.

[11] OECD Nuclear Energy Agency, Nuclear Energy Outlook, Paris, 2008
[12] International Energy Agency; *World Energy Outlook*, 2008
[13]G Cooperman, *Beyond Peak Oil: A Survey Based on Primary Statistics,* 2004 available at: http://www.ccs.neu.edu/home/gene/peakoil/

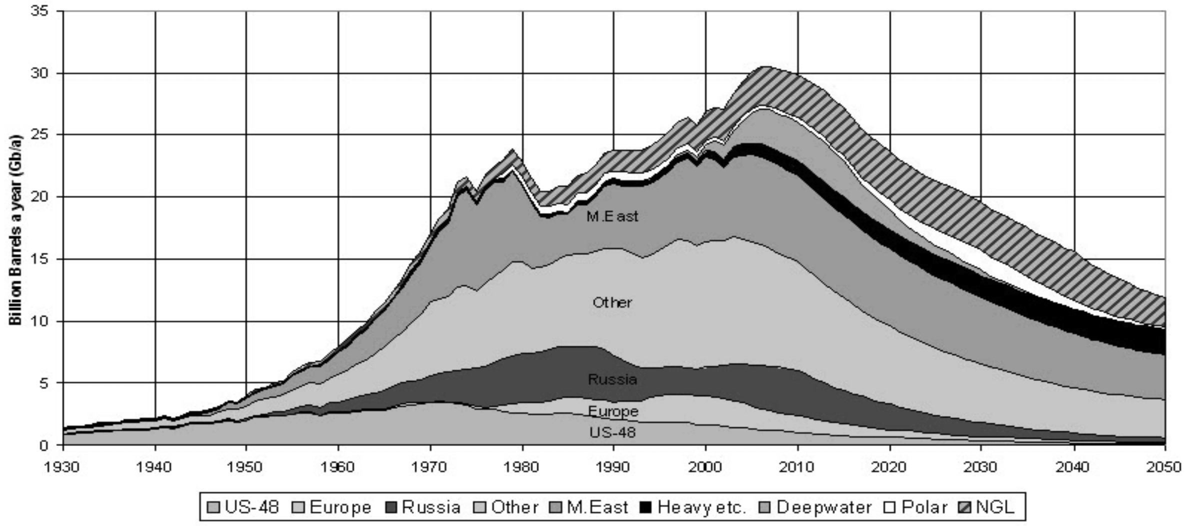

Figure 5: Industry projection of world oil production

This situation has led to increasing prices for oil, which are likely to remain at high levels, and has driven efforts to develop alternative fuels where this is feasible. Figure 6 below[14] shows the movement of oil prices over the last 35 years. Energy planners accept that oil prices are very unlikely to ever return to the levels experienced up until 2000.

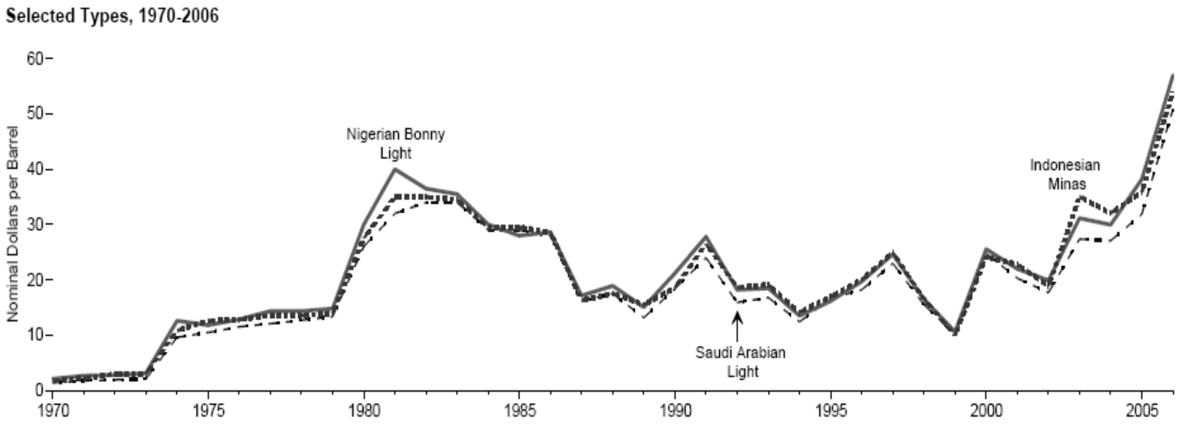

Figure 6: Movement in oil prices over the last 35 years

Recently the increased demand for natural gas, coupled with some supply problems, has seen very significant price increases - of the order of a factor of four compared with the prices of the early 1990s. The Figure 7 below[15] shows the movement in gas prices over the last 55 years.

[14] US DOE Energy Information Administration website, available at: http://www.eia.doe.gov/emeu/mer/pdf/pages/sec9_2.pdf

[15] US DOE Energy Information Administration website, available at: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec6_16.pdf

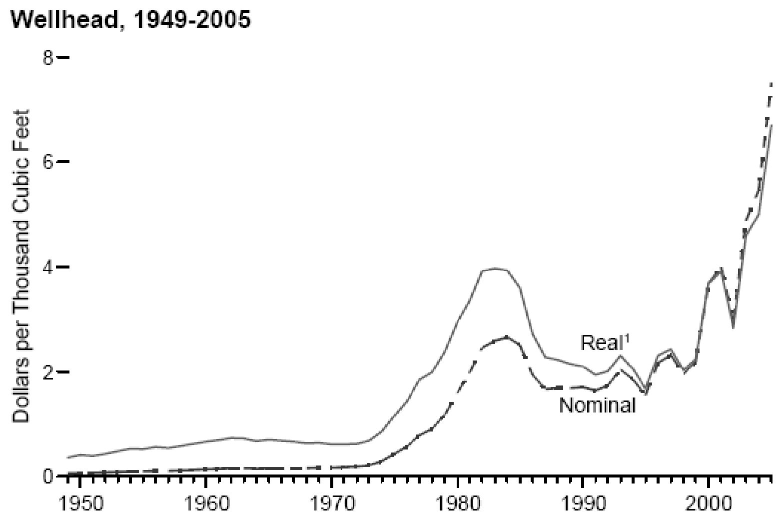

Figure 7: Wellhead price of gas plotted over the last 55 years

When considering the relative prices of these energy sources, one must also consider the effect of a rise in the price of the raw material on the price of electricity to the consumer. The cost of electricity from a nuclear power plant has a uranium price sensitivity of about 4% (i.e. a 100% increase, or doubling in uranium prices translates to a 4% increase in electricity price), while the corresponding sensitivity for coal is 40%, and that for gas is 75%, see Figure 8.[16] In these times of volatile price movements for energy commodities, nuclear offers reassuring stability.

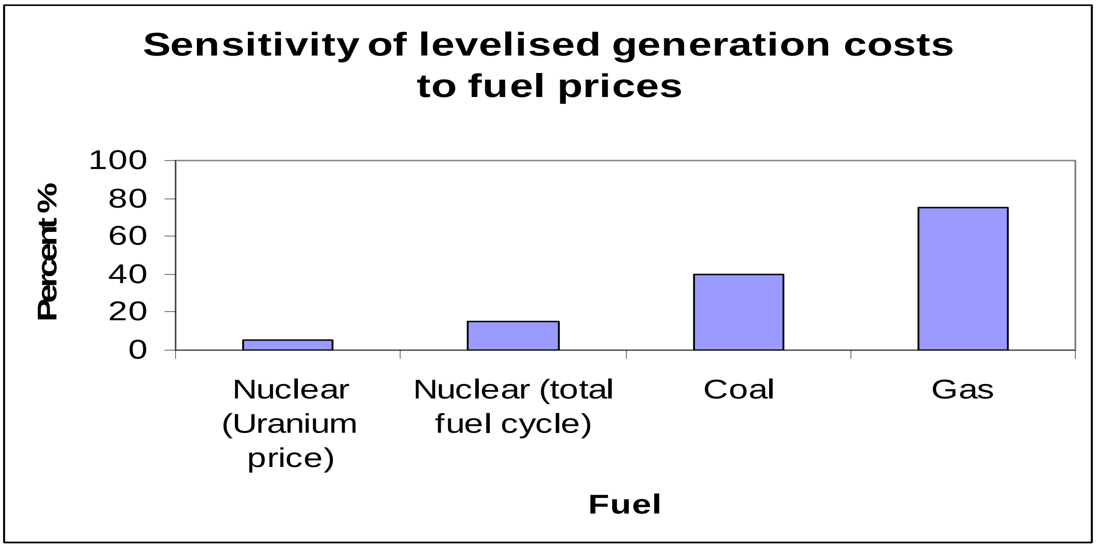

Figure 8: Sensitivity of levelised generation costs to fuel prices - percent increase in generation cost with a doubling of fuel cost[16]

3.1.4 Global challenges

There are two major global energy challenges to be faced by countries today,

1. Securing a reliable and affordable supply of energy
2. Providing clean energy while reducing carbon dioxide emissions

To prevent the predicted catastrophic effects that climate change will produce it is necessary for a major decarbonisation of the world energy sources. In the Nuclear Energy Outlook by the NEA, it notes that electricity generation accounts for about 27 % of global anthropogenic CO_2 emissions and is by far the largest and fastest-growing source of green-house gases.[11] Nuclear power can provide an essentially carbon free source of base load energy supply and is being embraced in many countries.

3.1.5 Why the world is turning to nuclear

Nuclear power currently supplies 15 % of the world's electricity from 436 reactors[10] and the interest in the development of nuclear power as part of the electricity generation portfolio has increased significantly in many countries.

The NEA Nuclear Energy Outlook states that this is because *"the demand for electricity continues to grow rapidly in many countries, leading to concerns about security of energy supply, future prices of fossil fuels and increasing greenhouse gas emissions. In a number of countries, the response to these concerns has been to propose nuclear construction programmes that not only add significant capacity but also increase the percentage of nuclear in the generation mix".*[16]

Figure 9 shows changes in nuclear electricity generation against changes in the nuclear share of generation between 2004 and 2020 for 22 countries expected to represent over 94% of the world's nuclear generation in 2020. The countries where both the absolute and relative nuclear contributions are expected to increase appear in the top-right quadrant, with thirteen countries currently utilising and two countries newly introducing nuclear power reactors. The average share of generation is projected to increase from 20.5% (in 13 countries) in 2004 to 25.0% (in 15 countries) in 2020.[16]

The United States and China have the largest planned increases in capacity. France proposes to build incremental additional capacity (it already has 77% nuclear generation; it will replace existing nuclear capacity when necessary). The Ukraine intends to increase its nuclear capacity by about 43% by 2020. Despite India's considerable expansion plans, its capacity in 2020 will be similar to that of Canada and the Ukraine. Several European countries – Belgium, Germany, the Netherlands and Spain – project reductions in their use of nuclear energy because they have adopted phase-out policies, although these are after 2022. It may be noted, however, that nuclear will still form a part of the energy mix of these countries for a considerable amount of time and that Sweden has recently announced a reversal of their decision to phase out nuclear.

[16] OECD Nuclear Energy Agency, *Nuclear Energy Outlook*, Paris, 2008

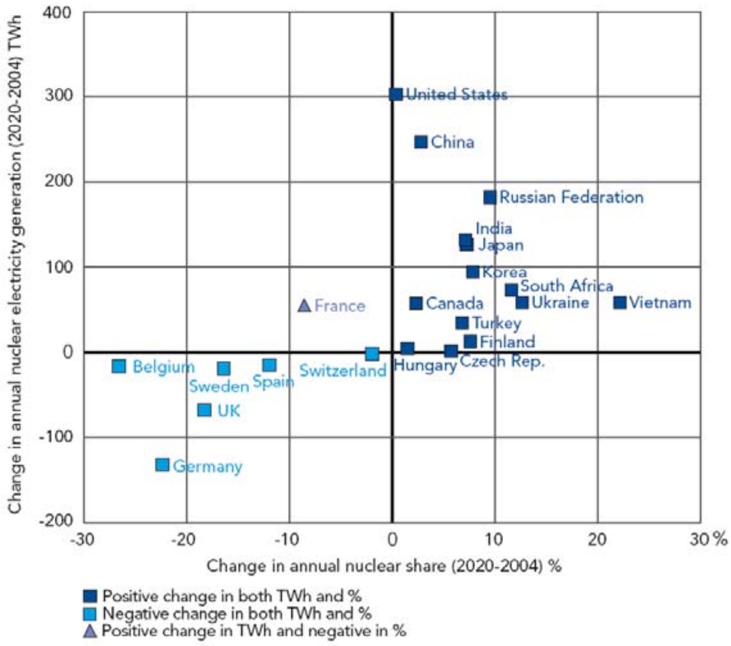

Figure 9: Changes in recourse to nuclear energy from 2004 to 2020[16]

Major countries without nuclear power – such as Vietnam, Turkey, Indonesia, Egypt, Kazakhstan and the Gulf Emirates – have already announced plans for introducing nuclear energy for the first time. Italy, the only country ever to shut down a small nuclear fleet and a country that it is now the world's largest importer of electricity, will reverse course over the coming decade.

The UK is currently in the process of expanding the share of nuclear power generation having realised that nuclear must be a key part of a secure and low carbon energy mix. The recently released paper by the UK Government, Road to 2010, states *"Nuclear power is a proven technology which generates low carbon electricity. It is affordable, dependable, safe, and capable of increasing diversity of energy supply" and is "therefore an essential part of any global solution to the related and serious challenges of climate change and energy security."*[17]

Also, the UK have set very high emission reduction targets (at least a 60% reduction in carbon dioxide emissions by 2050, and a 26-32% reduction by 2020, against a 1990 baseline) and mention in their White Paper that "*the modelling indicates that it might be possible under certain assumptions to reduce the UK's carbon emissions by 60% by 2050 without new nuclear power stations. However, if we were to plan on this basis, we would be in danger of not meeting our policy goals*:

- ***security of supply:*** *we would be reliant on a more limited number of technologies to achieve our goals, some of which (e.g. carbon capture and storage) are yet to be proven at a commercial scale with power generation. This would expose the UK*

[17] UK Cabinet Office; The Road to 2010 – Addressing the nuclear question in the twenty first century; July 2009

to greater security of supply risks, because our electricity supplies would probably be less diverse as a result of excluding nuclear; and

- ***reducing carbon emissions:*** *by removing one of the currently more cost effective low carbon options, we would increase the risk of failing to meet our long-term carbon reduction goal."*[5]

3.2 Australia

3.2.1 Australian energy mix

Figure 10 below shows the make up of Australian electricity generation as released by the Australian Energy Market Operator (AEMO). It can be seen that Australia is heavily dependent on fossil fuel with 93 % of electricity generated from burning fossil fuel. Of that 93 %, coal makes up 81 % and gas makes up 12 %. Hydroelectric power provides 6 % of electricity to the Australian energy mix, however given the substantial environmental impact that large dams have on the Australian environment, and the lack of suitable areas for dam development it is unlikely that there will be further hydro development.[18] The share contributed by gas has been increasing due to its use in peaking plant, and the 13 % Gas Scheme in Queensland.[19]

As discussed in the Uranium Mining Processing and Nuclear Energy Review by the Australian government in 2006[19], the Australian Electricity industry has approximately 48 Gigawatts (GW) of installed capacity.[20],[21] Base load plant capacity comprises approximately 70% of the generating fleet, but supplies 87% of electricity delivered. Base load plant, with low marginal costs, is generally dispatched for much longer periods than peak and intermediate plant.[22]

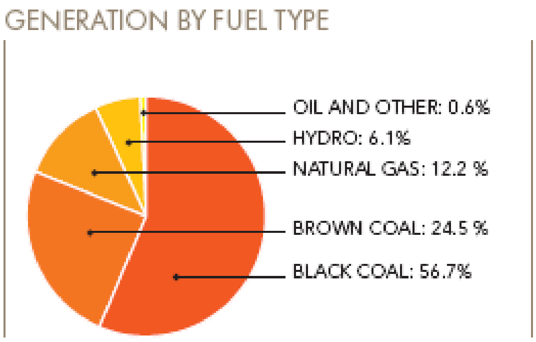

Figure 10: Australian electricity generation mix by fuel type[23]

[18] Mike Roarty; Science, Technology, Environment and Resources Group; Renewable Energy Used for Electricity Generation in Australia; 10 October 2000 http://www.aph.gov.au/library/Pubs/rp/2000-01/01RP08.htm#therenew

[19] Department of the Prime Minister and Cabinet, *Uranium Mining Processing and Nuclear Energy – Opportunities for Australia?*, Canberra, 2006

[20] Geoscience Australia. Excel file of all operating renewable generators. 24 July 2006, Australian Greenhouse Office. http://www.agso.gov.au/renewable/operating/operating_renewable.xls (Accessed 15th July 2009)

[21] Geoscience Australia; Excel file of Operating fossil fuel power stations; 18th July 2006, Australian Greenhouse Office; http://www.ga.gov.au/fossil_fuel/operating/operating_fossil.xls (Accessed 15th July 2009)

[22] Australian Bureau of Agricultural and Resource Economics; *Energy in Australia 2005*; Canberra, 2005

[23] Australian Energy Market Operator (AEMO); *An Introduction to Australia's National Electricity Market*; July 2009

3.2.2 Growth of energy consumption

Australian electricity consumption has increased more than threefold over the period 1974-1975 to 2004-2005, to approximately 252 TWh. Gross electricity generation is projected to rise from 252 TWh in 2004-05 to 408 TWh in 2029-30 at an average growth of 1.9 % per year[24]

The Australian Bureau of Agricultural and Resource Economics (ABARE) have released projections for Australian energy supply and little change is projected in the relative shares of electricity from fossil fuels or renewables over the projection period, the main change being in the sectors fuel mix of an increase in the share of electricity generated from gas from approximately 14 % in 2004-05 to 23 % in 2029-30 and a corresponding decrease is projected in the share of electricity generated from coal (both black and brown) from 77 % in 2004-05 to 68 % in 2029-30. The share of renewables is projected to increase slightly, to 8 % by the end of the projection period which is not currently in line with the Australian governments renewable energy target of 20 % of Australia's electricity supply to come from renewable energy sources by 2020.[24] In similar manner, no major energy projection study anticipates a large increase in renewables and no OECD country has demonstrated that it can run a grid system with large amounts of intermittent power.

3.2.3 Challenges for Australia

Australia is the third highest CO_2 emitting country in the developed world; see Figure 11.[25] Electricity generation within Australia creates 50 % of the CO_2 emitted, higher than many countries. This is due to Australia's high dependence on fossil fuel. [23]

The Australian Government has set a maximum emissions reduction target of 15 – 25 % by 2020 with an unconditional emission reduction target of 5 % on 2000 levels by 2020. This is regarded by many climate scientists as too low at either level, but these were chosen to be affordable. To achieve the target, a Carbon Pollution Reduction Scheme (CPRS) will be implemented in 2011 which specifically seeks to place a cap on carbon emissions across various industry sectors of the economy. Over time, the CPRS should change industry and consumer behaviour as the costs of carbon are factored into the goods and services provided by industry to the community.[26]

The introduction of the CPRS leads to another energy challenge for Australia: increases in the cost of electricity generation from coal and gas. Currently it is economically viable to produce sufficient electricity from fossil fuel (however it comes with significant environmental cost). The CPRS will increase the cost of electricity generated by burning

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[24] Australian Bureau of Agricultural and Resource Economics (ABARE); *Australian Energy - National and state projections to 2029-30 – abare research report 06.26*; December 2006

[25] United Nations Statistics Division; Environmental Indicators – Climate change, September 2007 http://unstats.un.org/unsd/environment/air_co2_emissions.htm (Accessed on 15 July 2009)

[26] Australian Energy Market Commission; Review of Energy Market Frameworks in light of Climate Change Policies, 2nd Interim Report; 30 June 2009

coal significantly, making it less affordable to the consumer and less economically attractive for further investment.

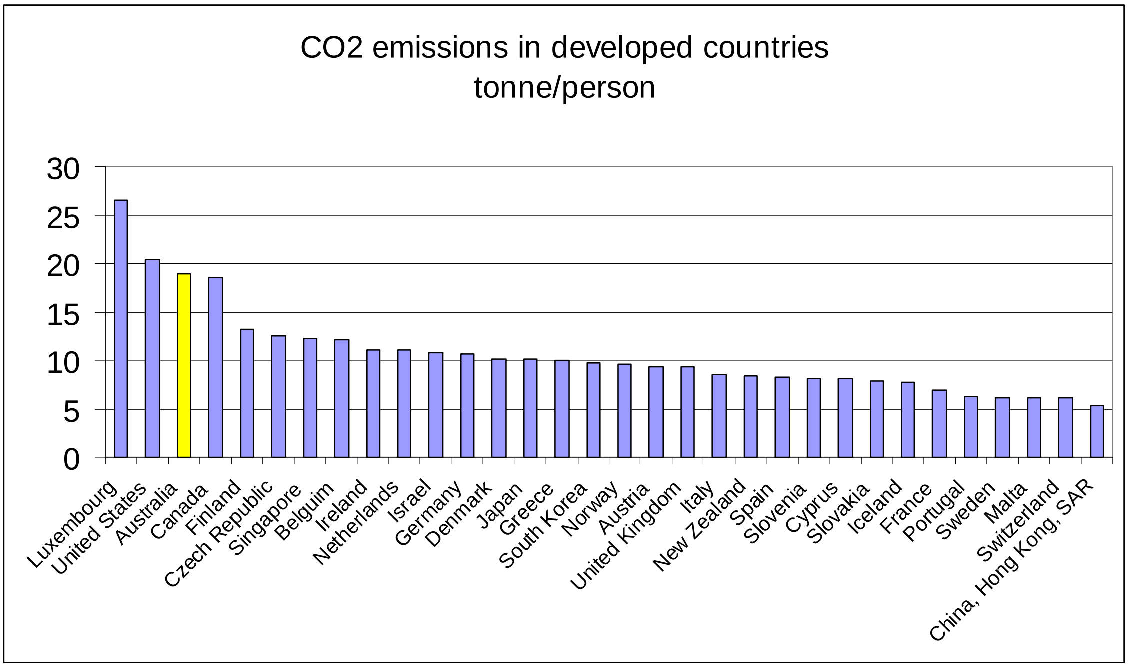

Figure 11: CO_2 emissions per capita in developed countries[25]

One further challenge for Australia is to be able to supply the increases in future demand for energy predicted to grow at about 2% per year. Findings from a recent international workshop held by ATSE on Electricity generation: Accelerating technological change which concluded that *'Energy security for Australia requires a major increase in base load electric power generation capacity to meet the expected growth in demand. This growth is independent of climate change and will still occur even with a much greater focus made on energy efficiency and conservation measures. Rationing and blackouts are inevitable in future once economic growth picks up. Governments must establish the necessary long-term, stable policy settings now to ensure large-scale investments are made in new generating capacity.'*[27]

3.2.4 Australia's chosen mainstream options for generating low carbon electricity

1. Clean coal:

Clean coal uses the carbon capture and sequestration technology (CCS) and can offer the prospect of lower CO_2 emissions from coal and gas firing. However it is not proven technology and still emits various amounts of pollutants, which affect the health of populations down-wind. The UMPNER[28] addressed CCS as follows:

[27] Australian Academy of Technological Sciences and Engineering (ATSE); *Electricity Generation: Accelerating Technological Change – International Workshop*, 2009
[28] Department of the Prime Minister and Cabinet, *Uranium Mining Processing and Nuclear Energy – Opportunities for Australia?*, Canberra, 2006

"*CCS remains to be proven except in highly specific applications (notably oil recovery from ageing wells). Uncertainties remain about the cost of CCS, and its reliability and security over the long term.*

CCS may be less effective in reducing emissions when retrofitted to existing plants and uses significant extra energy and additional complex plant. This increases the cost of electricity produced.

Policies that price greenhouse and other emissions would further reduce the competitiveness of CCS compared to nuclear power because CCS technologies, even on optimistic scenarios, are expected to remain more pollution intensive" as the carbon capture might not capture all the CO_2 or other pollutants such as particulates, SOx and NOx.

The US Department of Energy released a Carbon Sequestration Technology Roadmap and Program Plan in 2007

- The goal of the program is to have a technology portfolio by 2012 for safe, cost-effective, and long-term carbon mitigation, management and storage.[29]
- The program is aiming for a < 10 % increase in the 'Cost of Energy services' which will enable fossil fuel systems with CCS to compete with other power generation options including wind, biomass and nuclear power. However, a ≥ 10 % increase would mean that CCS would not be an economically competitive option for low carbon electricity generation.[29]
- The report also goes on to say that the three main cost components of CCS is capture, transport and storage and then states that "*the cost of capture is typically several times greater than the cost of transport and storage, and could increase electricity production costs by 60-100 % at existing power plants and by 25 to 50 % at new advanced coal-fired power plants*" [29]

2. Gas:

An increase in the amount of gas used in Australia's future electricity production is predicted by ABARE[24]. Gas is being utilised because the upfront construction costs are cheaper that than of a coal or nuclear power plant, however gas as a fuel is very expensive.

The sudden increase in gas plant construction is reminiscent of the UK 'Dash for Gas' where UK electricity companies built many gas fired power plants due to high interest rates and the discovery of North Sea Gas[30]. Gas will be taking a smaller part of the energy mix in the UK as domestic production from the North Sea gas fields continues to lessen.

[29] U.S. Department of Energy – Office of Fossil Energy, National Energy Technology Laboratory; *Carbon Sequestration Technology Roadmap and Program Plan*; 2007

[30] BBC News; *The politics of power*, April 2004 http://news.bbc.co.uk/2/hi/uk_news/politics/3581637.stm accessed on 22/7/09

Globally, gas prices have risen inexorably and have placed strain on economic development in many countries.

As well as the increase in cost of gas due to the CPRS, the increased demand for gas for electricity generation will cause the price of gas to jump, and it is also projected by the National Energy Security Assessment (NESA) that the affordability of gas in 15 years will be low due to higher reserve exploitation costs and production will be increasingly dependent on reserves that are more difficult to access.[31]

3. **Hydroelectric power:**

Hydroelectric power provides 6 % of electricity to the Australian energy mix, however given the substantial environmental impact that large dams have on the Australian environment, and the lack of suitable areas for dam development it is unlikely that there will be further hydro development.[32]

4. **New renewables:**

The Australian government has set a Renewable Energy Target of generating 20 % of Australia's electricity using renewable technology by 2020. Clean electricity from 'new renewables' – solar, wind, biomass and geothermal power – deserves strong support. But none of these 'new renewable' technologies are at an advanced enough stage to offer reductions in the medium term. The International Energy Agency projects that, even with continued subsidy and research support, these new renewables can only provide around 6 % of world electricity by 2030. No country is known to have demonstrated renewable generation for base load power (with the exception of hydropower, which is at, or near capacity in Australia, as previously mentioned). The problem of low efficiencies from wind and intermittency remains a problematic issue.

4 The role of nuclear in energy security

Fossil fuel is relied on heavily in Australia because it has a low cost of production but the economic viability comes at significant environmental cost with the production of large amounts of CO_2 gas (among other air pollution). Australia needs to heavily reduce the amount of carbon emissions released into the atmosphere to meet targets set by the Australian Government. While Australian emissions are less than 1% of global emissions, Australia will be greatly impacted if global warming occurs at the rate predicted.

However, another challenge for Australia that may not be quite as obvious due to the abundance of natural resources is energy security. Australia's electricity generation is highly dependent on fossil fuels. Given that Australia is planning to reduce carbon emissions by implementing a carbon cap and pricing scheme (as well as other measures),

[31] Australian Government, Department of Resources, Energy and Tourism; *National Energy Security Assessment*, 2009

[32] Mike Roarty; Science, Technology, Environment and Resources Group; Renewable Energy Used for Electricity Generation in Australia; 10 October 2000 http://www.aph.gov.au/library/Pubs/rp/2000-01/01RP08.htm#therenew

the cost of electricity will increase. In this section, we examine energy security, taking on board the points outlined in the 'Challenges for Australia' section, and the option of diversifying Australia's energy mix to include nuclear is explored.

4.1 Definition of energy security

The Department of Resources, Energy and Tourism conducted a National Energy Security Assessment, released in 2009, which defined energy security as the adequate, reliable and affordable supply of energy to support the functioning of the economy and social development[31], where:

- **Adequacy** is the provision of sufficient energy to support economic and social activity;
- **Reliability** is the provision of energy with minimal disruptions to supply; and
- **Affordability** is the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.[31]

While the above points are valid, to be able to adequately compare the different options for energy production it is also necessary to include **environmental impact** and **public health and safety** as a part of the assessment criteria.

4.2 Is Australia's future supply secure?

4.2.1 Assessments of Australian Energy Security

The National Energy Security Assessment 2009 (NESA) analysed the current energy situation as well as projecting into the future to assess the security of Australia's energy, assuming no large energy mix changes.[31] The assessment concerning projected electricity security is shown in Figure 12 below. It is shown that Australia will have a moderate level of energy security with the adequacy and reliability of supply being rated as moderate, but the affordability being rated as low. This is the same for all future predictions in the NESA (5, 10 and 15 years hence). A rating of low means that the economic and social needs of Australia are not, or might not be met. A low rating means that the energy sector and/or energy users are significantly affected by major shocks to the energy system, thus the cost of electricity will become extremely sensitive to any cost changes that occur within the energy generation process, which will then be passed through to the consumer. The rating of low affordability is mostly due to carbon pricing and gas supply issues but also reduced water availability, a lack of infrastructure resilience and an expanded Renewable Energy Target. The NESA also found that it would be necessary to diversify energy generation to assist in managing supply shocks and to invest in frameworks for converting energy resources for delivery of energy to the economy.[31]

Fifteen year electricity security assessment

Issue Impact on:	Adequacy	Reliability	Affordability	Assessment
Reduced water availability				
Gas supply issues				
Carbon pricing				
Expanded RET*				
Implementation of market reforms*				
Infrastructure resilience				
Overall assessment	Moderate	Moderate	Low	Moderate

Key: Negative impact; Slightly negative impact; No impact; Slightly positive impact; Positive impact

Figure 12: NESA Fifteen year electricity security assessment[31]

4.2.2 Comparison of energy options

To effectively compare energy options, we need to add environmental impact and public health and safety impacts to give an expanded set of criteria. Figure 13 below shows a comparison table with each of Australia's energy options (as outlined in section 3.2.4): coal, gas, hydroelectric, renewable technologies and clean coal, as well as nuclear, all assessed using the expanded criteria.

Technology	Adequacy	Reliability	Overall Affordability	Environmental Sustainability*	Health and Safety
Coal	Adequate fuel supply within Australia	Base load generator	Sensitive to fuel price - see fig 9. Cost will increase with CPRS	High CO2 emissions, particulates, NOx, SOx	Poor safety record; high pollution-related illnesses
Gas	Adequate fuel supply within Australia, future fuel availability may decrease	Reliable supply	Currently moderate, will increase with demand and CPRS	Moderate CO2 emissions	Moderate safety record
Hydroelectric power	Limited capacity available in Australia	Reliable supply	Affected by water availability	Causes major impacts on the environment. Requires water; already at capacity	Poor safety record; no pollution-related illnesses
Other renewables	No base load power available	No base load power available	High capital and low operating costs	Low emissions; little to no waste	Good safety record; no pollution-related illnesses
Coal with CCS	As yet unproven technology	Base load generator	Unknown; Retrofitting may increase prices 60-100%	Technology doesn't remove other pollutants	Unknown; Will be similar to coal
Nuclear Fission	Adequate fuel supply available. Very adequate with reprocessing	Very high capacity factor - very reliable supply	V. high capital and low operating costs. Depends on a number of factors**	Low emissions; produces small volumes of high level radioactive waste that can be encapsulated	Good safety record; no pollution-related illnesses

Figure 13: Comparison of Australian electricity generation options
*Refer to Figure 14 for comparison of life cycle air pollution, NOx and SOx.
See Section 7: Economics of nuclear power

On this analysis, we conclude that coal, clean coal and gas do not provide adequate energy security and that renewables are, as yet, not sufficiently commercially demonstrated to provide significant amounts of energy. Nuclear power, however, is a demonstrated, low carbon option.

Figures 12 and Figure 13 show that the lack of diversity from Australia's reliance on fossil fuels for electricity makes the future energy supply potentially insecure. Figure 13 also shows that Australia's economic position becomes more vulnerable if a price on carbon (through, for example, the CPRS) is introduced. Unless the future energy supply is diversified to include other generation options such as nuclear power, any increase to the price of coal and gas, as well as carbon will have a significant impact on the price of electricity which will affect the end consumer as well as making investment in the industry less attractive.

Given Australia's large output of CO_2 per capita, it is necessary to use the lowest carbon option available to provide sufficient electricity for the increasing demand. Looking at Figure 13, Australia's major carbon mitigation strategies are carbon capture and sequestration, renewable technologies and the adoption of nuclear power generation. The current policy of pursuing clean coal and renewables should be supported but does not provide early or proven solutions to the problems Australia faces. Australia's energy security depends on clean coal being available in a short time frame and at an affordable price, but neither assumption can currently be sustained. The worldwide evidence is that clean coal will not be economical in the required time frame. Also, there is currently no renewable technology available that can provide large base load power, and much development of technology is still needed.

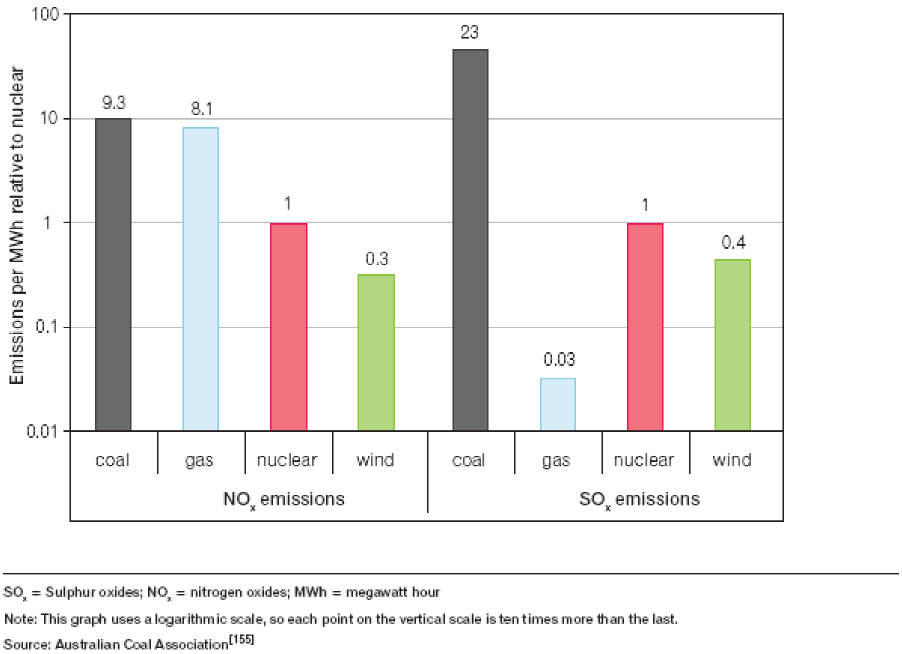

Figure 14: Estimated life cycle air pollution from different technologies NOTE: logarithmic scale[28]

4.3 Nuclear is key within a diverse energy mix

One option to enhance security for Australia's energy supply is to introduce diversity from the current strong dependence on coal and gas by developing renewable technologies and establishing nuclear power generation. The introduction of nuclear generation into the Australian energy supply would give the advantage of a reliable and affordable base load supply with low carbon emissions. Also, the stable price of nuclear electricity generation (due to low effect of fuel price on generation price) means that nuclear power is broadly competitive in cost terms with other energy sources (Refer to Section 7: Economics of nuclear power).

Many countries around the world are realising that diversity in energy mix is a key defence against unexpected events. This was a key driver in the UK turn-around from not seeing a role for nuclear in 2003 to advocating strongly in 2006 onwards[33]. The UK White Paper notes: '*We will continue to need fossil fuels as part of a diverse energy mix for some time to come. But in order to meet our carbon reduction goals, sources such as coal and gas must become cleaner. And it is in our own vital interests that the technologies necessary to mitigate the emissions from burning fossil fuels are developed and deployed as rapidly as possible – especially as fossil fuel use by emerging economies, such as China and India, is growing rapidly as their economies expand. Carbon capture and storage (CCS) is an emerging combination of technologies which could reduce emissions from fossil fuel power stations by as much as 90 %. CCS with electricity generation has not yet been proven on a commercial basis, although some key elements of the process have been demonstrated.'*[33]

UMPNER[28] states that the most flexible and efficient system is likely to include numerous technologies, each economically meeting the portion of the system load to which it is best suited. In a well functioning system, a diversity of sources can also provide greater reliability and security of electricity supply.

In Australia, there is increasing recognition by business of the potential role of nuclear power in a future generating mix. The NSW Business Chamber examined these issues in their report "Powering NSW" dated March 2009 and concluded: *"All levels of Government need to consider alternative, low carbon energy sources when planning for future electricity generators. This includes the current Federal and State Governments abandoning their ban on nuclear power plants."*[34]

The ATSE International Workshop for Energy Generation: Accelerating technological change, contributors indicated that *'nuclear energy needs to be a part of the future base load portfolio in their countries if deep cuts in greenhouse gas emissions are to be met. Concern was expressed that, by continuing to exclude consideration of domestic nuclear power, Australia is placing considerable base load reliance on the technological and financial viability of as yet unproven CCS and geothermal energy technologies. It would be prudent to undertake further work on the reduction of technological, regulatory and*

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[33] Department of Trade and Industry; *Meeting the Energy Challenge – A White Paper on Energy*; United Kingdom; May 2007

[34] NSW Business Chamber; *Powering NSW*; March 2009

other risks, including an understanding of the formation of community attitudes to nuclear power generation.[27]

5 Nuclear in the Australian context

5.1 Nuclear technology

Nuclear technology is constantly developing – the technology first utilised in the 1950s and 1960s has improved dramatically, especially in key aspects such as fuel efficiency and most importantly, reactor safety. The following diagram shows the progress of reactor technology over time.

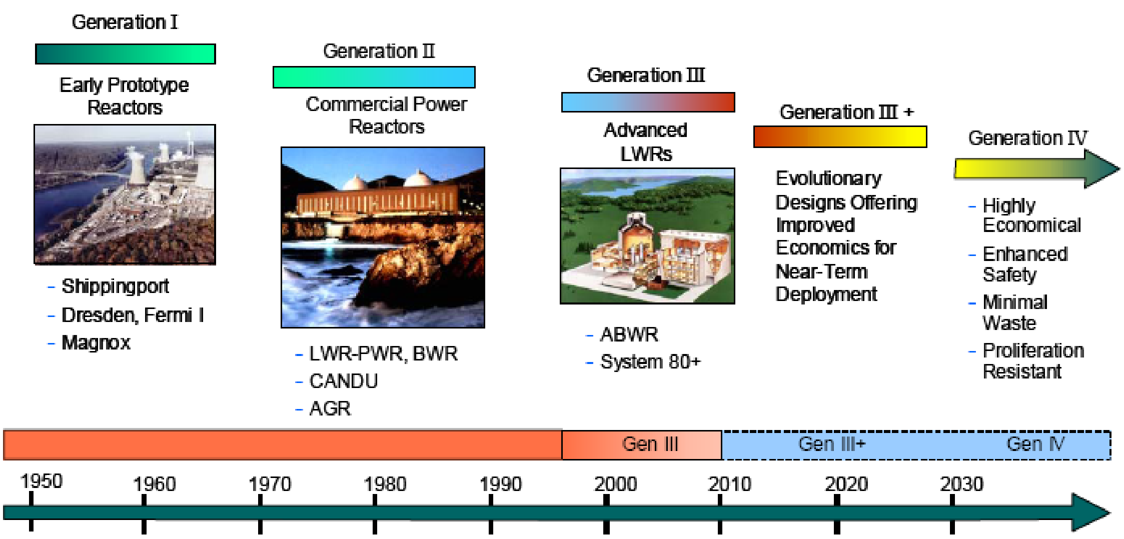

Figure 15: Evolution of nuclear power reactors[35]

The progress from Generation I to Generation III reactors represents a steady evolution of technology, while the move to Generation IV represents a revolutionary change in technology. The benefits of Generation IV include major advances in waste reduction, proliferation resistance and enhanced safety features.

In order to lower the cost of building a first reactor, it is in Australia's best interest to opt for an established Gen III design. The most obvious candidates for consideration are:

- EPR a 1,600 MWe (Megawatt electrical) Pressurised Water Reactor (PWR) from the French company AREVA, based on previous PWR designs by Framatome and Siemens, both of which have been subsumed into AREVA.
- AP1000 a 1,117 to 1154 MWe PWR from Westinghouse (now part of Toshiba), based upon the earlier AP600 model.

[35] US Department of Energy, *A Technology Roadmap for Generation IV Nuclear Energy systems*, Washington, December 2002

- ABWR or ESBWR a 1,350 or 1,560 MWe Boiling Water Reactor (BRW) from General Electric, based on earlier BWRs.

All these designs are the latest in a line of proven reactor models, and examples of each are being built around the world. The first EPR is being built in Olkiluoto, Finland, with the second underway in Flammanville, France, and negotiations underway for more in China and Taiwan. Four ABWRs have been built in Japan, with two more nearing completion in Taiwan. Proposals for AP1000 and ESBWR reactors are currently being developed for a number of sites in the USA. The advantages of building an established design are the reduction or elimination of "first-of-a-kind" (FOAK) costs, lessening of financial risk associated with construction of the reactor, improved regulatory approval and efficiency due to the use of "certified designs" and the benefits associated with an experienced workforce.

5.2 Advantages of nuclear

5.2.1 Maturity of technology

Nuclear power has been providing electricity since the 1950s, and is well established in a number of OECD countries. In regards to adequacy of energy supply, one need look no further than the case of France, the world's fifth largest economy, which derives almost 80% of its electricity from nuclear power[36]. In terms of reliability, global average availability of nuclear power currently stands at approximately 83%, although three countries (the Netherlands, Slovenia and Finland) achieved more then 95% availability, with another six countries achieving more than 90%. Between 1990 and 2004, 57% of the growth in nuclear output was not from building new reactors, but from increasing availability of existing reactors[37]. Finally, in terms of affordability, while nuclear power involves very high capital costs, in established nuclear markets, operational and maintenance costs are very low. Also, the price of nuclear power is very stable when compared to power generated by fossil fuels, due to the low price sensitivity associated with the uranium fuel.

Most significantly, nuclear power is a mature technology – it has a proven track record in many countries around the world, including the leading economies.

5.2.2 Economic Factors

The construction of nuclear power plants involves large capital costs when compared to fossil fuel technologies – approximately 50-60% of the final cost of the power is attributed to capital costs. However, once established, the operating and maintenance costs of nuclear power are very low[38]. The cost of nuclear power generation decreases with the construction of each new nuclear power plant.

[36] OECD Nuclear Energy Agency, *Nuclear Energy Data*, Paris, 2007
[37] OECD Nuclear Energy Agency, *Nuclear Energy Outlook*, Paris, 2008
[38] OECD Nuclear Energy Agency, *Nuclear Energy Today*, Paris, 2003

Another key economic advantage of nuclear is its low price sensitivity. As price stability is a key aspect of maintaining affordability of energy supply, the stability of nuclear power operations make it useful in achieving overall energy security.

Nuclear is already cheaper to generate than most renewable sources, and nuclear power also increases in economic competitiveness if a price on carbon (e.g. a carbon tax) is introduced[39].

5.2.3 Environmental Factors

The generation of nuclear power emits no carbon dioxide into the atmosphere. Even when taking into account the emissions associated with uranium mining, processing, transport and enrichment, the use of the world's known resources of uranium would still save approximately 180 billion tonnes of carbon dioxide being emitted into the atmosphere[40]. Nuclear power can play a key role both in Australia's domestic energy security and in reducing Australia's carbon emissions.

In addition to greenhouse gas emissions, nuclear has other environmental advantages. Volumes of radioactive waste are relatively small when compared to those generated by other industries, comprising less than 1% of total toxic waste[41]. Figure 16 shows the amount of waste per GW/year generated by nuclear and other energy sources:

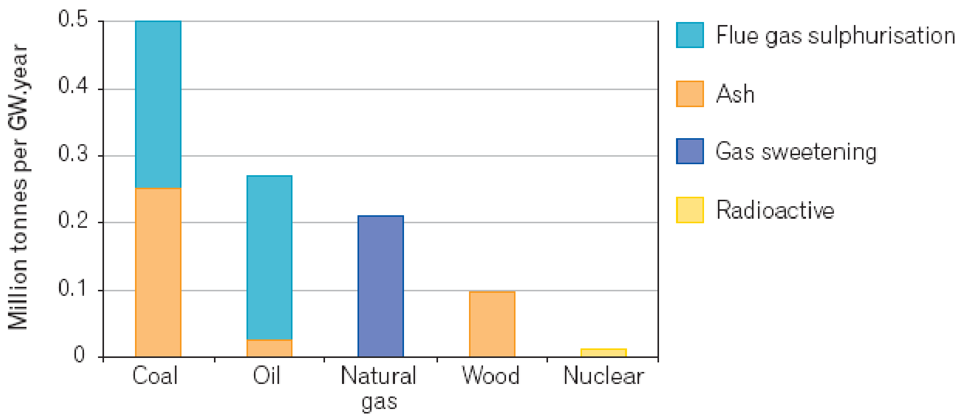

Figure 16: Waste produced in fuel preparation and plant operations for a variety of fuel sources[42]

[39] Electric Power Research Institute, *Review and comparison of recent studies for Australian electricity generation planning: Report for UMPNER*, Palo Alto, 2006

[40] Lenzen, M., "Life Cycle energy and greenhouse gas emissions of nuclear energy: A review", *Energy Conversion and Management* 49, 2178-2199

[41] World Nuclear Association, "Waste management in the nuclear fuel cycle", WNA, 2009 http://www.world-nuclear.org/info/inf04.html, accessed July 2009

[42] Rosen, M., "Managing Radioactive Waste: Issues and Misunderstandings", 23rd Annual International Symposium of the Uranium Institute, London, 1998

5.2.4 Future technology developments

Internationally, efforts are underway to further improve the standards of nuclear power generation technology. The Global Nuclear Energy Partnership (GNEP) and the Generation IV Forum are two international movements aiming at developing future technologies that directly address issues such as efficiency, waste generation, health and safety and non-proliferation. Although it is unlikely to be a reality until at least 2030, the development of Gen IV reactors has the potential to greatly extend the lifetime of fuel deposits, increase energy output and offer greater proliferation and physical protection capability. Most reactors currently in operation are Gen II light water reactors, with most new reactors to be Gen III or Gen III+ (there are currently 4 Gen III+ reactors under construction).[43] While not available now, advances in nuclear power technology will further improve the viability of nuclear within a diverse energy mix.

5.3 Issues and concerns

There are a number of concerns raised about the use of nuclear power in Australia. These include waste and environmental impact, proliferation, security, health and safety and the capacity of the nuclear market. These issues are not new concerns, and each of these concerns has been extensively examined.

5.3.1 Waste and environmental impact

The disposal of radioactive waste is a concern raised by many members of the community in relation to nuclear power. Radioactive waste arises from a wide range of applications involving radioactive materials. Waste can take many different forms, from materials that may be lightly contaminated (such as paper and clothing) to highly radioactive substances (such as spent fuel). Waste is characterised as either being low-level (LLW), intermediate-level (ILW) or high-level waste (HLW). When compared to the volumes of waste generated by other industries, the volume of radioactive waste from nuclear power plant operation is small. In countries with nuclear power, radioactive wastes comprise less than 1 per cent of total industrial toxic waste.

In terms of radioactive waste management, the technology and practices have been developed to encapsulate, store or dispose of radioactive waste safely and effectively for the long periods of time required. Repositories for LLW and short-lived ILW are established in many countries and have been safely managed for many years. The repository is required to maintain containment for some hundreds of years, after which the radioactivity will have decayed to background levels.

Long-lived ILW is generally stored pending disposal as with HLW. However the US , Finland and Sweden have announced or are operating HLW repositories and other countries, such as France and Japan have processes underway. In reality, most countries

[43] OECD Nuclear Energy Agency, *Nuclear Energy Outlook*, Paris, 2008

have been slow to implement deep geological repositories until significant volumes of waste have been generated.

The preferred long-term disposal option for direct disposal of SNF and/or HLW is deep, permanent geological disposal. Internationally, it has been accepted that geological disposal is an ethically and environmentally sound waste management solution[44]. Granite, clay, salt and tuff have been investigated in a number of countries as host formations for repositories. All of these formations provide the necessary setting to isolate wastes from the bio-sphere over geological time-scales. Generally, the OECD/NEA[45] notes that, for a well chosen site, the barrier systems and host rock are reasonably predictable over 10^5 to 10^6 years and that shorter term uncertainties can be bounded with some confidence.

5.3.2 Proliferation and security

In terms of non-proliferation and security, we note the conclusion from the Director General of the Australian Safeguards and Non-proliferation Office that there are no safeguards impediments to the introduction of nuclear power into Australia[46]. Australia has excellent credentials on non-proliferation and has an effective regulatory system, consistent with the best practices around the world and fully in compliance with international safeguards. This has been confirmed by inspections from the IAEA and other international agencies. Typical reactor operation generates plutonium in the spent fuel; however, this grade of plutonium presents a low proliferation risk as it is not suitable for use in nuclear weapons. When proliferation has occurred in the past, it has involved illegal supply networks, secret nuclear facilities and undeclared materials, not the diversion of declared, nuclear materials from nuclear power plants[47].

High levels of physical protection are now built into the new reactor designs and the requirements for assurance of resistance to terrorist attack are very demanding. Recent assessments show that a modern reactor is well protected from such attacks.

5.3.3 Health and safety

Following the incidents at Three Mile Island and Chernobyl, there was great public concern regarding the operation of nuclear power facilities. The international nuclear energy industry has learned significantly from the experiences of these events, and the

[44] OECD/NEA, The Environmental and Ethical Basis for Geological Disposal: a Collective Opinion of the Radioactive Waste Committee, OECD/NEA Nuclear Energy Agency, Paris, France (1995) http://www.nea.fr/html/rwm/reports/1995/geodisp/geological-disposal.pdf

[45] OECD/NEA, The Handling of Timescales in Assessing Post-closure Safety Lessons Learnt from the April 2002 Workshop in Paris, France, NEA No. 4435, OECD/NEA Nuclear Energy Agency, Paris, France (2004) http://www.nea.fr/html/rwm/reports/2004/nea4435-timescales.pdf

[46] Australian Safeguards and Non-proliferation Office, Submission to UMPNER, ASNO, 2006

[47] Department of the Prime Minister and Cabinet, *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?*, Canberra, 2006

standards of nuclear safety now far exceed those that were in place before these incidents more than 20 years ago.

Chernobyl remains the only nuclear energy accident to result in fatalities. Fifty six people are known to have died as a direct result of the Chernobyl incident, and a comprehensive, multi-agency study (using established statistical dose-effect models) concluded that a total of the order of 4000 fatalities might be ascribable to the disaster but would be virtually impossible to identify against the normal cancer incidence[48]. It should be noted that scientists involved were reported to oppose publication of such a specific estimate without actual data.

It must be emphasised that apart from the Chernobyl disaster, no nuclear workers or members of the public have died as a result of exposure to radiation from a commercial nuclear power reactor incident. This compares favourably with other forms of current energy technology. A study by the Paul Scherrer Institute of Switzerland, which maintains a database of industrial accidents, shows that more people die as a result of the activities of coal, gas, LPG and hydro electricity generation.

	OECD		EU-15		Non-OECD	
Energy chain	Accidents	Fatalities	Accidents	Fatalities	Accidents	Fatalities
Coal	75	2259	11	234	102 1044 (a)	4831 18'017 (a)
Oil	165	3789	58	1141	232	16'494
Natural Gas	80	978	24	229	45	1000
LPG	59	1905	19	515	46	2016
Hydro	1	14	0	0	10	29'924 (b)
Nuclear	-	-	-	-	1	31 (c)

(a) First line: Coal non-OECD w/o China; second line: Coal China
(b) Banqiao and Shimantan dam failures together caused 26'000 fatalities
(c) Latent fatalities treated separately

Figure 17: Severe accidents (at least five fatalities) for a number of energy chains

When this data is related to the amount of electricity produced, there have been 0.006 fatalities per GWe.year of nuclear electricity, compared to fifteen times as many fatalities for natural gas, and about a thousand times as many fatalities for coal, oil and hydropower. This data shows that, contrary to common belief, nuclear power is a safe option for generating electricity.

In regards to exposure to the public as a result of routine operations, using conservative population estimates, UNSCEAR calculated that people near sites where these activities are carried out would receive approximately 40 μSv per year. This is considerably less

[48] Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience Report of the UN Chernobyl Forum Expert Group "Environment" (EGE), IAEA 2006

than both the regulatory requirements and natural background radiation levels. These dose estimates are consistent with studies that have been performed in Australia[49].

As a comparison, a 500 megawatt coal-fired power station will produce coal waste containing 2.6 tonnes of uranium and 6.4 tonnes of thorium[50]. It will also release more radioactivity into the atmosphere than a nuclear station.

The perception of nuclear power as being unsafe to both workers and the general public is therefore not supported by evidence. Even taking into account the disaster of Chernobyl, nuclear power boasts a much stronger safety record than other electricity generators, with fewer accidents and fatalities.

5.3.4 Engineering Capability

It is recognised by the NEA[51] that a number of factors, including an ageing work force, a slow down in nuclear construction in the 1980s and 1990s, and reduction in government nuclear research funding, have lead to a major consolidation of the nuclear construction industry, limiting the capacity for new power plants. As old reactors reach the end of their generating life time, this will further increase the pressure on the nuclear construction industry to maintain the same levels of supply.

The problem of developing and maintaining existing and new skills in a competent work force has been recognised as a priority by the NEA. A number of OECD countries have launched initiatives, both domestic and international, in order to address this. These initiatives have included the World Nuclear University, the Nuclear Education Grant Program in the USA and the European Training and Education in Radiation Protection. These are small but important steps in reinvigorating the nuclear work force[52].

As demand increases and support for nuclear power grows, the engineering capabilities of the industry will also grow to meet that demand. However, support from governments, education and research institutions will also need to grow to help meet those demands, and to maintain the rigorous operational, safety and environmental standards of the nuclear power industry. Current estimates from the NEA claim that capability can be built to construct 35-60 1000 MWe reactors per year, growing to 70-120 1000 MWe reactors per year in 2050. The "high scenario" of the NEA's *Nuclear Energy Outlook 2007* assumes a construction rate of 10 reactors per year, rising to 20 by the late 2020s. A construction rate of 30-40 reactors per year is anticipated for the 2040s, reaching 60 units per year by 2050. There are currently 37 reactors under construction, so even given a high demand scenario, the NEA believes there is sufficient capability to meet this demand[53].

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[49] Crouch, P., *et al*, "Radiation Doses to Members of the Public from the Olympic Dam Operation", *Radiation Protection in Australasia* Vol 22, # 1, 2005

[50] McBride, J. P. *et al*, "Radiological Impact of Airborne effluents of Coal and Nuclear Plants", *Science* 8, 202, pp. 1045-1050

[51] OECD/NEA, *Nuclear Competence Building*, Paris, 2004

[52] OECD Nuclear Energy Agency, *Nuclear Energy Outlook*, Paris, 2008

[53] Ibid.

6 Government issues to be addressed

6.1 Commonwealth legislation

At the moment, Commonwealth legislation prevents significant parts of the nuclear fuel cycle, including nuclear power reactors, from being established in Australia. In particular, *Environment Protection and Biodiversity Conservation Act 1999* effectively prevents the construction or operation of nuclear fuel fabrication plants, nuclear power plants, enrichment plants or reprocessing facilities[54].

This is complemented by the *Australian Radiation Protection and Nuclear Safety Act 1998*, section 10 of which effectively prevents the CEO of ARPANSA from licensing the siting, construction or operation of such facilities[55]. The *Australian Radiation Protection and Nuclear Safety Act* applies only to Commonwealth agencies, and therefore does not prevent State governments from licensing such facilities.

6.2 State legislation

The NSW *Uranium Mining and Nuclear Facilities (Prohibitions) Act 1986* prohibits uranium mining and the construction and operation of nuclear facilities, including enrichment facilities and nuclear reactors (although there is an exemption for the research reactors operated by ANSTO and for nuclear-powered vessels)[56]. The Victorian *Nuclear Activities (Prohibitions) Act 1983* prohibits uranium mining and the construction and operation of nuclear facilities, including enrichment facilities and nuclear reactors[57]. Queensland allows for uranium exploration, but Queensland government policy does not allow for uranium mining. The Queensland *Nuclear Facilities Prohibition Act 2007* prohibits the construction and operation of nuclear facilities, including conversion, enrichment, fuel fabrication and nuclear reactors[58]. South Australia and Western Australia have legislation banning the construction or operation of a nuclear waste storage facility, but do allow for the mining of uranium.

6.3 Regulation

ANSTO's existing nuclear facilities are subject to regulation by a range of bodies. In the nuclear field, the two regulatory authorities involved are:

- The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), pursuant to the *Australian Radiation Protection and Nuclear Safety Act 1999*; and
- The Australian Nuclear Safeguards and Non-proliferation Office (ASNO), pursuant to the *Nuclear Non-Proliferation (Safeguards) Act 1987.*

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54 *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
55 *Australian Radiation Protection and Nuclear Safety Act 1998* (Cwlth)
56 *Uranium Mining and Nuclear Facilities (Prohibitions) Act 1986* (NSW)
57 *Nuclear Activities (Prohibitions) Act 1983* (Vic)
58 *Nuclear Facilities Prohibition Act 2007* (Qld)

ARPANSA's primary responsibilities are for safety and radiation protection; ASNO's are for nuclear material accounting and control (safeguards) and the physical protection of nuclear material and nuclear facilities. In practice, both agencies assert some degree of jurisdiction over security matters, and it would be desirable for responsibilities in that field to be more clearly delineated and aligned.

The differences in requirements for nuclear material accounting and control and physical protection which would be required by an expansion of the nuclear industry in Australia seem to be only matters of degree. ASNO are already experienced in tracking nuclear material through a range of fuel cycle facilities through their responsibility for accounting for Australian uranium sold overseas, and with the necessary augmentation of resources could perform those functions at any new fuel cycle facilities located in Australia.

On the other hand, although the basic radiation protection principles are the same, the safety requirements for nuclear power plants would require an increase in the size and expertise of the Commonwealth regulator.

In ANSTO's view, it would be desirable for the regulation of nuclear power plants to be undertaken at Commonwealth level, as the States and Territories have very little experience on which to draw. To establish regulatory authorities with the sufficient expertise in each relevant jurisdiction would also be inefficient. We also believe that it would be easier for a federal regulatory body with existing overseas links, such as ARPANSA, to licence the construction of a facility of a design already approved by a major Western regulator.

6.4 Nuclear Liability

The International Atomic Energy Agency and the OECD Nuclear Energy Agency have developed an international regime covering compensation for damage sustained from nuclear activities, known as civil nuclear liability. Most countries undertaking nuclear activities have developed national legislation consistent with that regime, irrespective of whether they are parties to the relevant international conventions. Exceptionally, Australia has no special legislation covering civil nuclear liability. Any such liability would therefore be determined according to the general tort law. There are significant differences between liability under general tort law and liability under the international nuclear liability regime. The principles of the international nuclear liability law include the following:

- The operator of anuclear installation is exclusively liable for nuclear damage. The operator – and only the operator – is liable for nuclear incidents to the exclusion of all others.
- Strict (no-fault) liability is imposed on the operator.

- Exclusive jurisdiction is granted to a single court in one country, to the exclusion of all other courts. The general rule is that a court of the Contracting Party in whose territory the nuclear incident occurs has jurisdiction.
- Liability is limited in time, and may be limited in amount.

Given the very significant potential liabilities which would arise in the case of nuclear power reactors and the major involvement overseas industry would have in the construction of such reactors, such legislation is an essential prerequisite for the development of a nuclear power industry. Once domestic legislation is passed, it would seem sensible to consider adherence to the international regime by ratifying one or more of the "modernised" Conventions. This would give greater certainty to the community and to potential nuclear suppliers.

6.5 Long term support

The introduction of nuclear power into the Australian energy market requires a high level of commitment, from the government, industry and the public. This commitment must also be long term, as it would take 10-15 years to construct the first power reactor and integrate it into the grid (although subsequent power reactors could be brought online in less time). A smooth, successful introduction of nuclear power would also require bipartisan support at the Federal level, and extensive cooperation between the Commonwealth Government and relevant State Government/s. Industry support is essential for the introduction and continued positive growth of nuclear power in Australia. Failure to secure bipartisan support would make nuclear technology companies significantly less likely to invest in Australian nuclear power.

6.6 Public opinion

The success of any nuclear power industry within Australia depends on support from the general public. Nuclear power remains a sensitive topic within many sections of the community. Concerns relating to safety, environmental impact and proliferation risks and terrorism are often cited as the reasons for opposing the development of a nuclear power industry in Australia. These were discussed above. Research conducted by the NEA indicates that acceptance of nuclear power increases proportionally with knowledge and experience of the industry. The problem is lack of knowledge and engagement with community stakeholders[59].

Despite a strong anti-nuclear movement within Australia, public opinion is turning in favour. A McNair Gallup poll from 2007 indicated that support for nuclear power has increased to 41%, up from 34% in a similar poll in 1979. Opposition had also decreased from 56% to 53%[60]. A similar poll conducted by Essential Media Communications showed support for nuclear power at 43% and opposition at 35%, with a large proportion

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[59] OECD Nuclear Energy Agency, *Nuclear Energy Outlook*, Paris, 2008

[60] McNair Ingenuity Research, "Support for Nuclear Power in Australia", Sydney, 2007

(22%) uncommitted[61]. These results, coupled with the examples set in the EU and the USA indicate that community engagement and education can grow the support of nuclear power with Australia.

7 Economics of nuclear power

7.1 Costs of establishing nuclear power in Australia

The key economic characteristics of nuclear power are as follows[62]:

- high capital investment costs
- low operational/maintenance costs
- low sensitivity to fuel costs
- long operational life
- significant regulatory costs
- significant decommissioning costs

In established nuclear markets, nuclear power is competitive with other sources of energy such as fossil fuels. The costs associated with establishing a nuclear power industry in Australia would also include the following costs:

- Cost of regulatory and legislative reform
- Costs associated with establishing the regulator
- Training and competence building
- Community education and consultation

Figure 18 shows a time line for a typical nuclear power plant in an established nuclear power market:

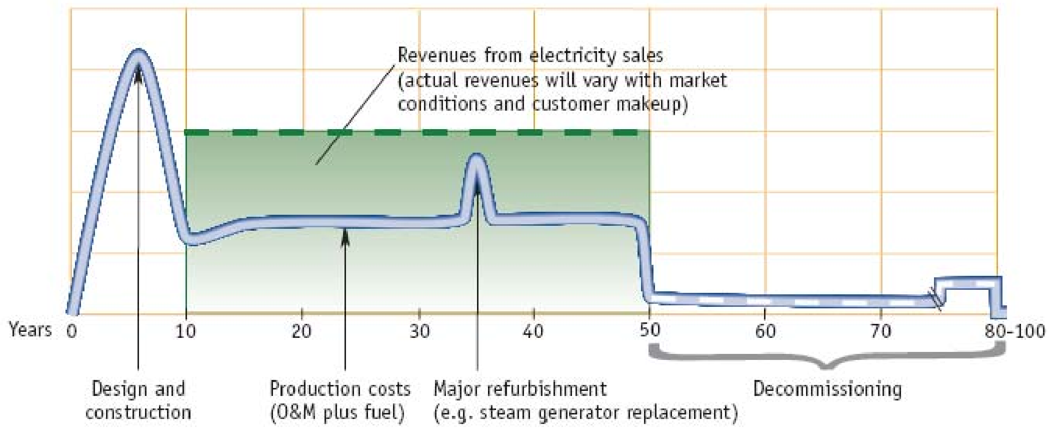

Figure 18: Timeline of costs associated with nuclear power generation

[61] Essential Media Communications, *Essential Report*, Sydney, January 2009
[62] OECD Nuclear Energy Agency, *Nuclear Energy Today*, Paris, 2003

7.2 Ways of financing nuclear power

Due to its high capital costs, investment in nuclear power plant building is often viewed as high risk activity. Given the high regulatory burden of establishing nuclear power in Australia, and the associated uncertainty with creating a new industry, these perceived risks increase even further. In practice, most countries that utilise nuclear power have started with government support in the form of government investment, subsidies or the protection of a regulated market[63].

It is mainly the risk associated with the large capital outlay (which represents 50-60% of the whole-of-life costs) associated with nuclear power that dominates issues regarding the financing of nuclear power. High capital investment, long lead- and life-times and regulation controls all increase the perceived financial risk associated with investing in nuclear. This is reflected in higher interest rates for nuclear projects, as investors need to be compensated for bearing the risk[64]. This makes nuclear investment more sensitive to interest rates than fossil fuel investment. Lower interest rates favour investment in nuclear: according to a study by the NEA and IEA, nuclear is the least expensive option at 5% interest rates, but overlaps with fossil fuel technologies at 10%[65].

Nuclear power is also more expensive in deregulated markets. This is because the "risk shield" offered by government-backed monopolies (who can transfer costs and risks onto tax payers) has been partially wholly removed by the deregulation. Again, this results in the risk being borne solely by the investors, increasing the costs of electricity generation. Australia does not have a fully deregulated energy market, so it would be possible for the Australian government to absorb the financial liability for a significant portion of the risk.

Gittus[66] assesses two plans for financing nuclear power in Australia. Both his plans are based on the Westinghouse AP1000 reactor being chosen. The first plan does not include any Government subsidy; however, it would give an insured loan which would then be repaid once the plant began producing electricity. The purpose of the loan is to cover the FOAK costs that would undoubtedly arise if Australia builds its first reactor. The risk of the project is shared between the insurers, the government, shareholders, banks, the vendor and the owner.

The second plan involves a Government subsidy, both in the form of a grant to cover some of the extra capital costs associated with building the first nuclear reactor in the country, and also in the form of electricity generating subsidisation. Similar schemes are being used in the US.

In practice, nuclear build projects have been undertaken using a number of financing routes that apportion risk differently. Early in the development of nuclear power, most power plants around the world were owned, constructed, operated and financed solely by government, or government-owned utility boards. This system is still in place for a

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[63]OECD Nuclear Energy Agency, *Nuclear Energy Today*, Paris, 2003

[64] Lim E. *et al*, *Review and comparison of recent studies for Australian electricity generation planning*, Palo Alto, 2006

[65] OECD Nuclear Energy Agency and International Energy Agency, *Projected cost of generating electricity*, Paris, 2005

[66] Gittus, J. H., *Introducing Nuclear Power to Australia: An Economic Comparison*, Sydney, 2006

number of French reactors, and also in Russia, India and China. For a market such as this, the major drawback is that the risk is 100% owned by the government, and by extension, the customer. Thus any increase in generating costs, such as delays and budget overruns, is passed on to the customers[67].

Many nuclear economies have privatised their utilities since the advent of nuclear power, leading to deregulated markets. In this scenario, merchant generators compete with each other, and financing for new build takes the form of equity and corporate debt. Such a market increases the price risk, which is usually mitigated by long-term power purchase agreements or support from a parent company. This corporate model of finance has been utilised by utility companies in Germany, Spain, the USA and Japan[68].

Many countries, including Finland, Canada and the United States now use "hybrid" finance plans for funding their new nuclear power plants. These plans share the risk between the owners, operators, vendors, investors and the government. How the risk is apportioned varies between projects, however, the government will usually take some or all of the risks associated with regulation, waste and decommissioning. Another approach is for the government offer a high-level of support early in the project, with the planning, pre-construction and construction phases, before refinancing to remove government involvement once the plant is operational[69].

Examples of financing routes for nuclear power include[70]:

- **Public-private partnerships** – particularly common for infrastructure projects in the United Kingdom, one example of this would involve a government-run competition for a company/consortium to build, own and operate a certain number of plants. The government would guarantee some FOAK costs, and be able to specify technology and locations
- **Balance sheet financing by utilities** – large utilities, particularly in Europe, have strong balance sheets that would allow them to finance even large capital costs, such as those required for nuclear power plants. The government can accept some of the risk for costs associated with regulation and decommissioning.
- **Project finance** – investors lend to a specific, one-purpose entity, whose only asset is the nuclear power plant and whose only revenue is from future power sales. Projects are highly leveraged, and equity only needs to be contributed at a later stage while their other assets are protected. A difficulty is finding appropriate rates for debt financing, however, the government can assist by guaranteeing loans. This is the proposal for new plants in the United States.

[67] Alizadeh, A., Atomic Energy of Canada Ltd, "Financing of Nuclear Power", IAEA Technical Meeting/Workshop on Milestones for the Nuclear Power Infrastructure Development, Vienna, 2007

[68] Alting von Geusau, A., "Preconditions for Financing Nuclear Power", IAEA Technical Meeting/Workshop on Milestones for the Nuclear Power Infrastructure Development, Vienna, 2007

[69] Bazile, F., French Atomic Energy Division, "Nuclear Power Plant Financing", IAEA Technical Meeting/Workshop on Milestones for the Nuclear Power Infrastructure Development, Vienna, 2007

[70] World Nuclear Association, *Structuring Nuclear Projects for Success: an Analytic Framework*, London, 2008

- **Power user investment** – this has been used to finance the Olkiluoto 3 reactor in Finland. Equity is contributed by heavy users of power, such as local utilities and industries. The users buy the electricity at cost, amortizing the debt portion from the market. If the plant operates well, the owners obtain cheap energy over a long period of time, avoiding the risks of the open market.

There are other strategies employed by governments to assist with the economic issues of nuclear build projects. Such strategies include tax concessions (in Brazil)[71], loan guarantees and protection against delays (in the United States)[72] and reduction in regulatory uncertainty and improvements in planning efficiency through legislative reform (in the United Kingdom)[73]. These strategies, combined with a variety of financing routes, indicate that while there isn't one correct approach to financing nuclear power, there are many options available in ensuring that the best route is adopted for a specific energy market. Given the investment made by the Australian Government for CCS and renewable technology, it is not unreasonable to suggest that similar investment could be made for nuclear power.

7.3 Comparison to other energy technologies

There have been a number of studies conducted in recent years, comparing the price of electricity generated by nuclear to that produced by gas and coal power plants. The results of these studies vary, depending on factors such as regional variability, although they do show that in most cases, nuclear can be competitive with coal and gas.

A study by EPRI in the USA for the UMPNER report took into account not only existing costs associated with energy generation, but the additional costs associated with the addition of carbon capture and storage into coal and gas electricity power cycles. Their findings are summarised in Figure 19.

This shows that while nuclear is competitive with gas, coal is cheaper, meaning nuclear would struggle to compete in the current market. However, when measures such as carbon capture and storage (CCS) are introduced, the price of coal and gas increase substantially, making nuclear power a much more competitive, attractive energy option. The introduction of carbon taxes (of the order of $15-40 per tonne of CO_2) on emissions would have a similar impact on the price of fossil fuels as energy sources, again making nuclear competitive. It is also worth noting that the cost of renewable energy varies significant from the competitive (hydroelectricity) to the extremely expensive (solar photovoltaic). This demonstrates that nuclear can play a significant role in delivering stable, affordable energy in an energy market affected by climate change mitigation schemes.

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[71] World Nuclear News, "Tax incentives for new Brazilian reactor", retrieved from www.world-nuclear-news.org/newsarticle.aspx?id=25643, on 21/07/09

[72] *Energy Policy Act 2005*, (USA)

[73] Department of Business Enterprise and Regulatory Reform; *Meeting the Energy Challenge – A White Paper on Nuclear Energy*, United Kingdom, 2008

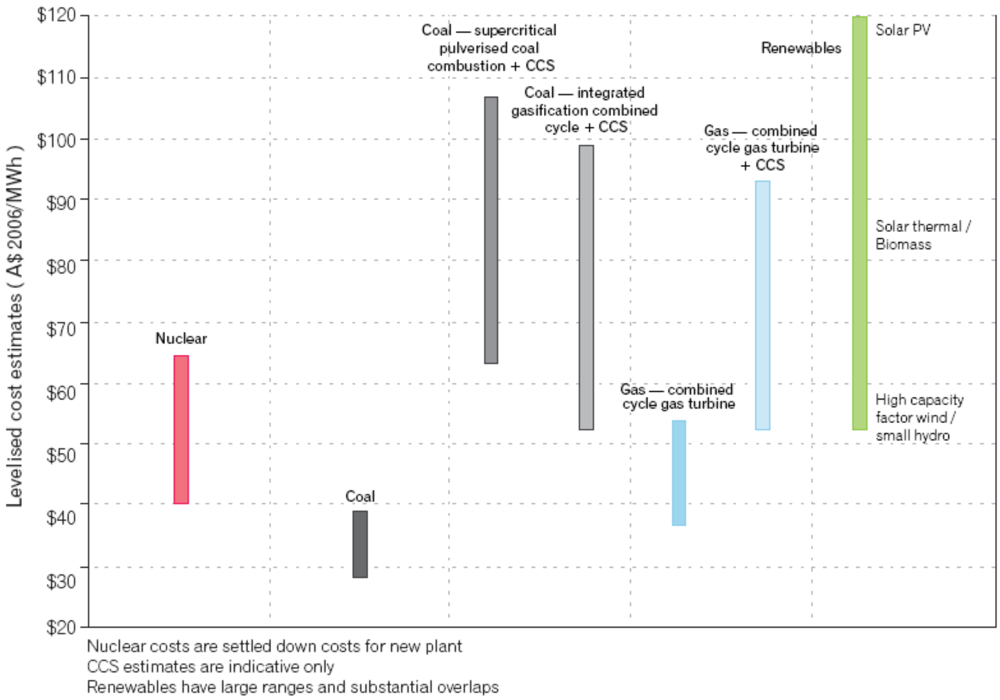

Figure 19: Levelised cost ranges for various technologies[74]

This analysis only takes into account direct costs. Externalities are costs or benefits that affect a third party, rather than the immediate participants in a market transaction. Externalities in the energy industry include the cost of the environmental and health impacts of using the technology. Figure 20 shows the external and direct costs of electricity generation in the European Union, as determines in the ExterneE report[75].

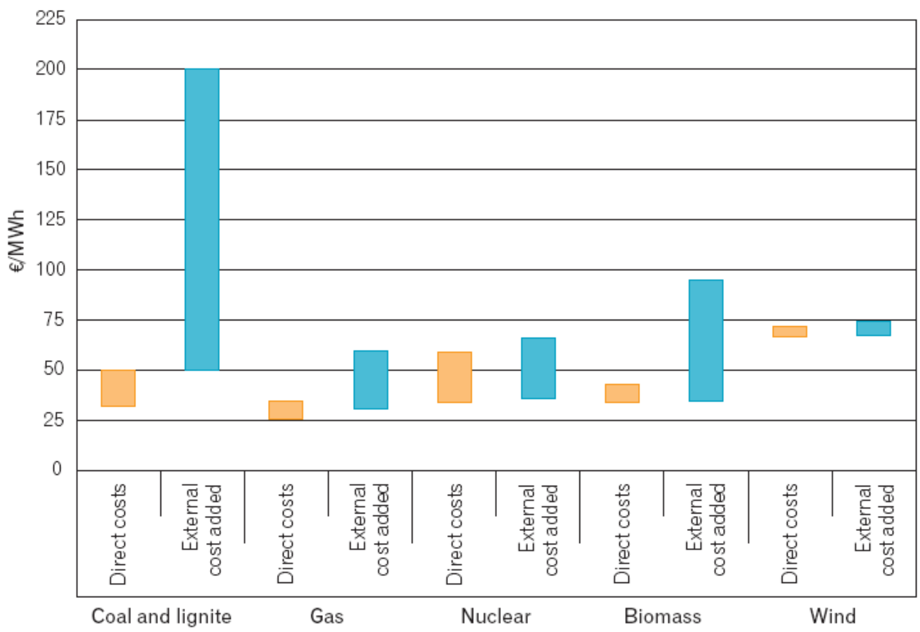

Figure 20: External and direct costs of electricity generation in the European Union

[74] Department of the Prime Minister and Cabinet, *Uranium Mining Processing and Nuclear Energy – Opportunities for Australia?*, Canberra, 2006

[75] European Commission DGXII, ExternE – Externalities of Energy Vol. 10: National Implementation, Brussels, 1999

From a societal point of view, externalities should be internalised, such that they are included in the cost of producing the energy. Strict regulations governing atmospheric emissions, liquid effluents and waste management mean that the majority of nuclear power's potential externalities are internalised, and included in the price of nuclear power. The externalities of nuclear and wind are of a similar order to the direct costs, whereas the external costs of biomass, coal and gas are much greater than their direct costs, mainly due to the CO_2 and other emissions they generate.

8 Conclusion

This report concludes that:

1. Current trends in global and domestic energy demand and consumption are expected to continue. These rates of increase are, however, unsustainable, and threaten both security of energy supply and climate stability.
2. A secure energy supply is characterised by good adequacy, reliability and affordability. It must also be environmentally sustainable, and have minimal adverse health effects. This is best achieved through the use of a diverse mix of low carbon and low pollution energy sources.
3. Most developed economies and a number of developing economies include nuclear power in their long-term energy security strategy. Australia is one of very few OECD countries not embracing nuclear power.
4. All OECD countries (except Australia, New Zealand and Iceland) that have not embraced nuclear power can and do import nuclear power from contiguous economies that have nuclear power. Australia will not have this option available to it – a significant negative for energy security if the intention is to remain a leading economy.
5. Australia currently relies almost exclusively on fossil fuels (especially coal) for its electricity supply. This lack of diversity and current dependence on sources with high greenhouse gas emissions makes Australia's future energy supply insecure. Australia's economic position becomes more vulnerable if a price on carbon is introduced.
6. The current policy of pursuing clean coal and renewables is a necessary but not sufficient strategy in the light of the climate change challenge. Renewables cannot yet provide early or proven solutions to the problems Australia faces. Depending on affordable clean coal being available in a short time frame is not supported by the science or the technological maturity of the technologies or the required regulatory assurance. The assumptions that underpin policy optimism in this regard cannot be sustained. In fact, worldwide evidence is that clean coal will not be economical in the required timeframe.
7. Nuclear power generation is a mature, proven technology that has provided base load power in a number of countries for 50 years. It has a number of advantages such as fuel price stability, low operating costs, low emissions and waste and, for Australia in particular, a secure fuel supply. Nuclear power has much to offer in the way of achieving a diverse energy mix, and thus, ensuring medium to long term energy security.
8. S Korea and Japan have continued to build nuclear plants in the "nuclear winter" that preceded the current nuclear renaissance and have developed good practices in both nuclear industrialisation strategy and regulatory processes from which Australia can learn.

9. The nuclear power industry in the developed world is the only electricity generator that also pays for its full lifecycle costs, including the cost of managing the waste it produces.
10. Nuclear power merits serious consideration as an option for Australia. The consideration should be based on a full evidence-based examination of the available technology along with a range of other technologies using established levelised cost analysis and properly pricing carbon within the analysis.
11. The best model of reactor to use for Australia would be a proven, reliable Generation III model (more passive safety systems and standardised plants than Generation II). These include the EPR (AREVA), AP1000 or AP600 (Westinghouse/Toshiba), ABWR (General Electric/Hitachi or Toshiba) or the ESBWR (General Electric/Hitachi). By the time, Australia makes a decision on any of these designs, there will be enough built or under construction that "first of a kind" issues will have been resolved.
12. Despite its maturity, it is clearly recognised that there a number of important public concerns raised about nuclear, including waste, proliferation and safety. These issues have been extensively examined in many countries and by many studies. These conclude that technological advances in the industry and its regulation mean that the residual risks are well controlled.
13. Active public engagement, transparent information and factual debate have been shown in other countries to significantly allay public concerns. Independent, strong regulators are also seen to be key to public confidence.
14. Significant regulatory and legislative reform must be undertaken in order for nuclear power to be established in Australia. Such reform is best achieved through sustained bipartisan support. Public education and community engagement are also merited so that debate and decisions are fact-based and transparent.
15. Concerns are also raised about the cost of nuclear power, due to its requirement for high initial capital investment. This requires special funding mechanisms and government support to reduce the risks from delays and provide incentives for investment. This is no different to the support given to other forms of energy production. Nevertheless, appropriate accounting for greenhouse gas and other emissions has made nuclear a competitive option in relation to existing coal and natural gas plants and a much better low carbon source.
16. While there are a number of ways to provide a secure and diverse energy mix for Australia, all will require reducing reliance on current fossil fuel technologies, and nuclear power, in combination with renewable energy technologies, satisfies the criteria for being considered a key technology.
17. Australia's energy security from a trade and economic point of view will be severely compromised if nuclear energy is not actively considered as: the future cost of carbon is not known and all renewable options are intermittent low power density sources that cannot be relied on for energy intensive processes such as transport and logistics infrastructure, national defence facilities/deployment, and

economic extraction of natural resources, which form the bulk of Australia's trading income.

Appendix 1: Future developments in nuclear power (from ANSTO submission to UMPNER)

In the medium term perspective, two international initiatives need to be taken into account; the Generation IV International Forum (GIF) and the Global Nuclear Energy Partnership (GNEP). These initiatives have potential to significantly change the nuclear industry over the next 30 years and beyond. These two initiatives are intimately linked, but should be considered separately. GIF is an international project to develop a number of advanced reactors that take a revolutionary step beyond Generation III, aiming to achieve improved sustainability, safety, proliferation resistance and economic performance. In contrast, GNEP proposes a new framework of business and political relationships, to establish reliable supply of nuclear technology while avoiding the proliferation of fuel cycle facilities.

The Generation IV International Forum (GIF)

GIF was formally initiated in 2002 and currently consists of a consortium of ten countries (Argentina, Brazil, Canada, France, Japan, South Africa, Switzerland, the Republic of Korea, the United Kingdom and the United States) plus Euratom. The Forum has also recently agreed to admit Russia and China to its membership.

The Generation IV roadmap, referenced previously, identifies six advanced reactor designs and the underpinning research that is required to develop these designs. These reactors include types that can be used to burn the long-lived actinides to reduce waste disposal requirements and also reactors that are well suited to hydrogen production, opening up the possibility of alternative clean-burning fuels. For Australia to gain maximum benefit from Generation IV reactors, we would benefit from joining GIF. This would enable Australia not only keep abreast of new development, but also to influence the broader Forum to help achieve our national non-proliferation goals. ANSTO has capabilities in high performance materials and nuclear waste treatment that could help gain entry into GIF. Participation will enable effective consideration of the potential to introduce Generation IV technology into Australia in the future.

The Global Nuclear Energy Partnership (GNEP)

GNEP seeks to builds on the Generation IV technologies to achieve a partnership approach to the fuel cycle, which would enable advanced recycling of nuclear fuel while controlling proliferation risks. GNEP represents a significant policy change for the US, which has, until now, pursued the once-through fuel cycle because of its aversion to reprocessing and the risks of extracted plutonium falling into the wrong hands.

GNEP was announced by US Secretary of Energy Bodman on 6 February 2006. It includes both domestic US and international elements covering the following goals:

- Expand domestic use of nuclear power
- Minimise nuclear waste
- Develop enhanced nuclear safeguards

- Demonstrate more proliferation-resistant recycling
- Develop advanced burner reactors
- Demonstrate small-scale reactors
- Establish reliable fuel services

The GNEP approach can be best understood by reference to the following figure.

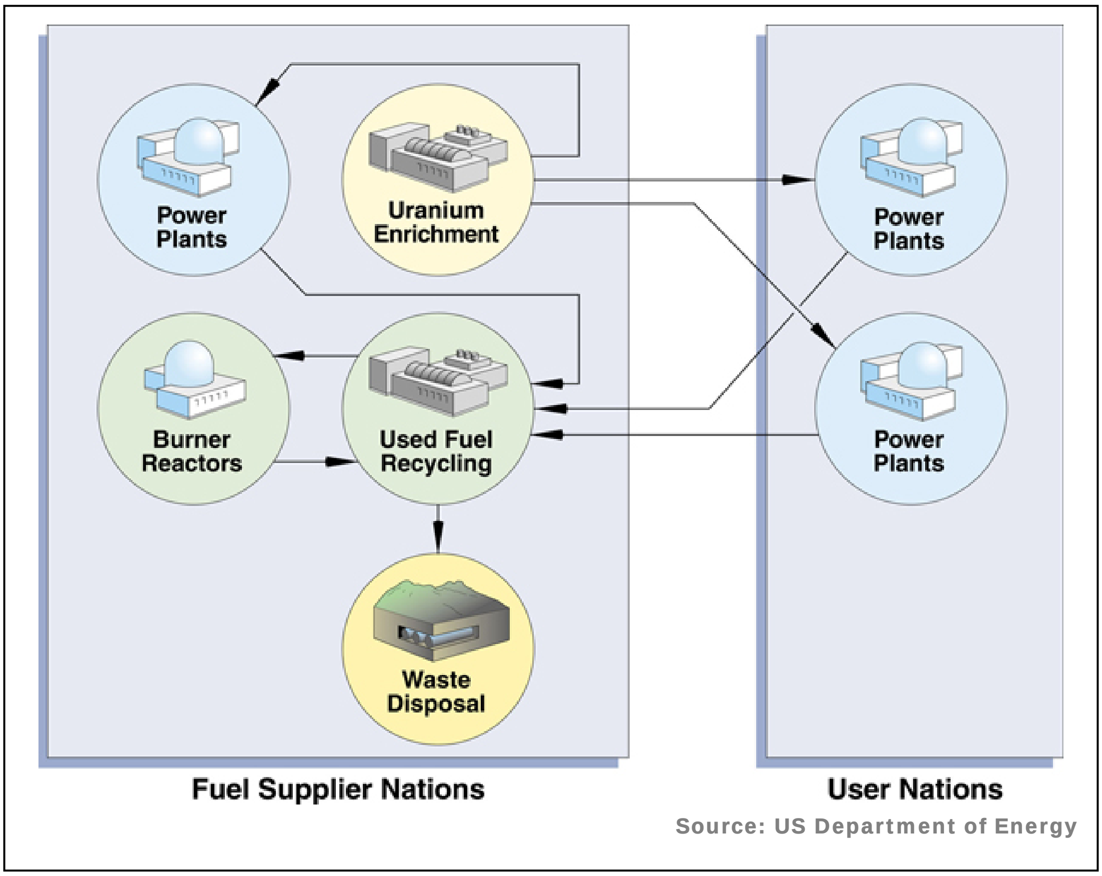

Figure 21: Materials flows in the Global Nuclear Energy Partnership[76]

The partnership is that between the "Supplier nations" and the "User nations". The former hold the technology and operate the fuel cycle facilities, in particular the enrichment and recycling facilities. The latter operate reactors, receiving fuel from the supplier and returning it for reprocessing or recycling.

Although Australia has carried out research on enrichment and reprocessing, we do not operate such facilities. Despite holding a third of the world's known uranium resources we are neither a supplier nor a user in the GNEP view of the world. There is a strong argument that Australia could boost its position as an energy superpower by entering the supplier side of the partnership. This would require a number of diplomatic, institutional and commercial obstacles to be cleared concerning access to, and the transfer of, the

[76] US Department of Energy, *GNEP Information Sheet: Establish Reliable Fuel Services*, 2 June 2006, available at: http://www.gnep.energy.gov/gnepReliableFuelServices.html

necessary technologies. In order to understand these obstacles and how to overcome them, it is necessary to understand more about the various steps in the nuclear fuel cycle. These steps will be explored in the next section of this report.

In addition to the fuel cycle implications, advanced reactor technologies are an integral part of GNEP. Two elements relevant to advanced reactor designs are worthy of mention before proceeding to look at the fuel cycle.

Advanced Burner Reactors

Advanced Burner reactors will be designed to "burn" or consume plutonium and other long-lived nuclides produced during the operation of light water reactors. ABRs would operate as fast reactors, that is, predominantly using high energy neutrons. ABRs will provide for an improved nuclear fuel cycle that allows for recycling of used LWR fuel. ABRs will be of a modular design to be operated either as stand-alone units or with several modules operating at a single site generating similar electrical output to LWRs. ABRs would undergo the same licensing process as Advanced LWRs currently undergoing design approval and certification. The US DOE intends to work together with other nations in the design and development of ABRs and build and build a test ABR to demonstrate the viability of the technology. It is anticipated that the first operational ABR could be available by 2025-2040, dependent on the amount of effort that is directed towards this goal.

Small Scale Reactors

The objective of the US DOE with regard to small scale reactors is to make available nuclear technology available to developing nations with low electricity demand without increasing the proliferation risk. The design would include physical protection and safeguards systems, passive safety systems. The reactors would be designed to have very long fuel life, requiring little or no demand for refuelling. They would have inherent safety features and be easy to operate. Their construction and operation would not require a well-developed regulatory infrastructure. The reactors would be of a standardised design in the range 50 – 300 MWe and could be used for a unique purpose, or for co-generation, such as electricity and heat generation for district heating, desalination or hydrogen production. These features make such designs ideally suitable to developing countries and emerging economies. Small reactors of this type would also be suitable for operation in isolated locations remote from a national grid, and could be of interest for application in Australia.

Appendix 2: Energy, revenue and CO2 produced from Australia's exported thermal coal compared to Uranium

It has been often remarked that Australia contributes only around 1% to global warming as a result of GHG emissions. This relates to its domestic emissions. However, Australia also contributes indirectly in terms of its export of coal and uranium.

Table 1 below shows the exports for 2007-2008 of both thermal coal and uranium, together with their energy equivalence, and the associated revenue (ABARE report). The energy equivalence is based on an energy density of coal of 6250 kWh/tonne and a thermal efficiency of 40 %.

	Sept	Dec	Mar	June	Total
Thermal coal (kt)	27,590	28,550	29,420	29,510	115,070
Electricity generated (TWh)	67.87	70.23	72.37	72.59	283.07
$m	$1,694	$1,802	$2,115	$2,754	$8,365
Uranium (kt)	2.49	3.09	2.39	2.18	10.14
Electricity generated (TWh)	103.8	128.9	99.55	90.99	423.19
$m	$285	$259	$172	$171	$887

Table 1 – exports for 2007-08 of both thermal coal and uranium, together with their energy equivalence, and the associated revenue

Coal generates about 10 times the export revenue than uranium does, but exports 10,000 times the volume. The smaller volume of uranium produces more than 50% more electricity. Table 2 below is based on the Energy in Australia Report 2009 and translates to similar figures.

	Mt	PJ	TWh	TWh (e)
Coal	115	3,105	863	259
Uranium (kt)	0.01014	4766	1323.8	436.91

Table 2 – exports of both thermal coal and uranium, together with their energy equivalence

In terms of GHG, the 115 Mt of coal exported will release about 288 million tonnes of CO_2 and the use of uranium in nuclear power plants wills save about 400 million tonnes (based on 1 kg/kWh emitted for coal and 10 g/kWh emitted for nuclear).

	Export (Mt)	CO_2 (Mt)
Thermal coal	115	288

Uranium (kt)	0.01014	4.41
CO_2 saved by nuclear		397

Table 5 – CO2 emissions for thermal coal and uranium

Hence Australia's net contribution from its exports is to reduce GHG emissions by around 100 million tonnes per year as a result of uranium sales. A similar type of saving would occur if uranium was used to fuel electricity generation in Australia.

Australia's uranium fuels approximately 46 one GWe nuclear plants, and thus is fuelling the equivalent of the Australian energy generating capacity and saving 400 million tonnes of CO_2 annually.

In the UMPNER, they estimated that 25 nuclear reactors producing about a third of the nation's electricity by 2050 would save about 170 million tonnes of CO_2 per year.